AN IMPROVED PACKAGING SYSTEM FOR LIVE WESTERN ROCK LOBSTER

Final Report

by

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EXECUTIVE SUMMARY

Marketing the western rock lobster has undergone a dramatic transformation over the last 5 years. For the 1993/94 season 2.8 m kg out of a catch of (ca) 11 million kg was marketed live, approximately 25.5%, compared with 5% of the catch, which was the norm 5 years ago.

The rock lobster industry has developed on its own initiative handling, processing and packaging systems for live rock lobsters largely on an 'ad hoc' basis.

The Rock Lobster and Prawning Association of Australia which includes amongst its members most WA lobster processors, packers and marketers, decided in 1993 that there was value in RLPA conducting and/or commissioning some applied post harvest research. Accordingly, it sought funds from the National Seafood Centre to conduct a research project into packaging systems used by its members during the 1993/94 rock lobster season. This project commenced in February 1994 and was completed in September.

The objectives of the research were,

1 To survey the packaging systems used with western rock lobster.
2 To determine the range of some physical parameters which may occur to western rock lobsters during transport, in particular, temperature, humidity, oxygen, carbon dioxide and ammonia levels.
3 To research into which packaging system best copes with the above physiological parameters.
4 To communicate the results to the fishing industry.

This report documents the findings of this research project. In summary these findings were:

1. Survey of packaging systems

Information on live packaging systems is scarce and of limited value in both the scientific and trade literature. Three papers exist in trade journals for lobsters. Prescott, (1980) for *Panulirus pencillatus* in the Solomon Islands, Lisac (1986) for lobsters in the Carribean, Chhapgar (1973) for Indian lobsters and Witham, (1970) reported live shipping details of Florida's spiny lobster *Homarus americanus*.
Considerably more information exists on live shipping details of prawns, Goodrick and Paterson (1992) Goodrick et al (1993) and Paterson (1993). This information although of considerable value considers a small short lived tropical shallow water crustacean and is limited in its application to a large longer lived warm temperate crustacean, with a deeper water habitat. Limited information also exists on blue crabs Otwell and Webb (1977) and Paterson et al (1993) for spanner crabs.

RLPA members were surveyed by two industry consultants during the 1993/94 season, re details and opinions of their packaging systems. The packout process was also observed on several occasions. The packaging systems used by RLPA members were basically similar, ie insulated polystyrene foam esky boxes with 2, 4, or 8 pencil size holes punched in the ends and containing 8, 9, or 10 kg net of live lobster, depending upon requirements of the customer. The packing material used was wood shavings at room temperature, of varied texture and fineness An ice bottle usually from -5°C to -35°C was added to the centre of the box. Boxes were overpacked with wood shavings, the lid forced on and tape placed around the join. In some cases tape was run over the box (banding) causing occasionally severe disruption to its contents. Cardboard outers or adhesive stickers were used to identify the box in the export market.

RLPA members considered the strengths of their packaging as being:
- that it worked;
- that they developed more knowledge and expertise with time;
- had become more cost effective.

The weaknesses they perceived as being:
- its high unit cost;
- extra weight of the materials which added to the freight bill;
- lack of control over transport system;
- the 'no responsibility' attitude of the airlines regarding live freight.

Some processors, however, felt that there had been a natural reluctance to trial alternatives commercially and that there was a general lack of knowledge and research regarding rock lobster and other live packaging systems.

2. Physical parameters

Temperature, pressure, and relative humidity were monitored during the transport process using small Hobo data loggers packed into the box, from packout in a live rock lobster receival facility to receipt by an export customer in Japan.

Data loggers showed that conditions within the box were largely influenced by external conditions be they within the processing factory, a refrigerated van during transport, in the cargo loading area at the airport, on the tarmac, or within the cargo hold of the aircraft. The polystyrene foam box was a poor temperature insulator. The punching of holes in the box further enhanced this poor insulating capacity. Research later indicated that holes in the box maybe important in achieving some gas exchange especially at higher temperatures. This research work was not absolutely conclusive and further investigation is required and should be undertaken by the rock lobster industry.

The presence of an ice bottle usually 1 litre in volume and placed in the centre of the box was found to assist, to a limited degree in reducing heat loss and absorption of heat when external temperature conditions were large. The ice bottle was found to control temperature largely for rock lobsters packed adjacent to it but caused damage and often subsequent

mortality to these lobsters when boxes were poorly handled particularly into AV containers at the airport. Poor handling practices at the airport were sadly observed on several occasions during the course of this project.

Lobsters were tracked whilst in transit to Japan using Hobo data loggers over a 28 hour period. Temperature extremes of 3°C - 38°C, relative humidity from 100% to 71% and pressure from 1000 - 1040 mbar were found. The Japanese customer visited, routinely documented from each lobster shipment, arrival temperature, ice bottle state, appendage loss and mortality (on arrival and 24 hours after retanking in seawater), as well as water quality parameters of his seawater. He had accumulated, over the last 5 years, a large quantity of live shipment receival condition data for western rock lobster, NZ lobster and *Homarus americanus.*

Experimentation procedures were developed using a Taylor 'Servomex and associated equipment to investigate the relationship between metabolic rate and temperature, during a 24 hour aerial exposure period, for the western rock lobster in the size range 607 - 717 gm. This preliminary research indicated that at 10°C the metabolic rate was gradually decreased and that at the end of the 24 hour test period rock lobsters were inactive and in good condition and health. Inadvertently, in one test, a higher incubator starting temperature had occurred. This led to an initial increase in metabolic rate which then decreased with time. This illustrated the benefit of maintenance of lower temperatures, of around 10C, during live transport.

Experimental tests conducted at 20°C, 25°C and 30°C, demonstrated a gradual increase in metabolic rate over time at temperatures greater than 20°C. Aerial exposure over 24 hours at 30°C killed the test lobster and subsequent testing was undertaken at the reduced temperature of 25°C. Results suggested that 24 hour aerial exposure of lobsters at this temperature was stressful and fatal to some. This experimental procedure has the capacity to study additional stressors such as disturbance, light, noise and humidity. Further work is recommended to this study.

An interesting observation of increased metabolic rate at sometime between 1000 and 0500 hrs occurred with lobsters at 10°C and with some other test lobsters at other temperatures. It is suggested that the diurnal pattern of activity and feeding at night which occurs with lobsters in the natural state does not appear to be lost during aerial transport in the dark in 10°C. This observation is worthy of further investigation.

3. Research into which packaging system best copes with the physiological conditions which occur during live transport.

Simulation experimentation was conducted using both canned tomatoes substituted for live lobsters and multichannel temperature recorders and live lobsters packed in a variety of ways. Comparisons were made with the industry standard for 1993/94, (polystyrene foam esky, punched with a hole in either end, filled with wood shavings at room temperature and a 1 litre ice bottle). Simulation procedures were undertaken over a 30

hour period and attempted to replicate the environmental conditions, in terms of temperature conditions which occur. They represent the most vigorous simulation procedures researched to date and included continuous monitoring of temperature, relative humidity and pressure.

Relative humidity was found not to be a dominant stress factor. It was found to be in excess of 70% for all simulation experiments, and above the critical level. Pressure did not fluctuate to any great degree during experimentation and was proportional to ambient temperatures of the environment to which packed lobster boxes were exposed. Temperature stress was the major factor concerning survival and condition of live lobsters. Research suggested a polystyrene foam box packed with wood shavings, a 500 ml ice bottle (rather than the standard 1 litre bottle) with two holes punched in either end is an acceptable alternative to the current packaging systems used in the western rock lobster industry. The poor insulation capacity of the foam box and the enhancement of this by punching of holes is of concern.

Simulation research using a 1 litre ice bottle and no holes against the industry standard of 1 litre and 2 holes was inconclusive. It was clearly shown that a combination of no holes in a box and a 500 ml ice bottle was detrimental to the health of lobsters. It appears that under certain circumstances the presence of holes in the box is essential to allow gas exchange. These require further investigation.

The alternative packaging materials (fillers) of hessian, foam and woodwool were tested against the industry standard material - wood shavings. Wood shavings significantly outperformed these alternatives in terms of better survival and condition. Thus there is benefit in the industry in continuing to use wood shavings as a packaging filler.

Since freight is an expensive component of live transport cost, it is possible for processors to decrease the size of the ice bottle from 1litre to 500 ml. Had this occurred for the 1993/94 season, a saving in the freight bill of the order of $680,000 would have occurred.

4. Communication

The enthusiastic participation of RLPA members and rock lobster processing personnel in this study resulted in survey and research results being communicated to them as they were discovered or shortly thereafter, as well as informally at RLPA meetings. This report will be distributed to all RLPA members to continue the communication process.

Simulation experiments were undertaken by Curtin University undergraduate and research students often in processing facilities. This had benefit as it illustrated to the processing industry, the time, techniques and devotion to the task required and that applied research is not simple in design or result.

It is worthwhile noting that during the latter half of this research program a Co-operative Research Centre proposed for research into 'Premium Marine Products' was prepared and submitted. It is proposed to involve the WA fishing industry, RLPA, WA Universities, as well as institutions and fishing industry personnel for South Australia and elsewhere in Australia. This research project is seen by some as a catalyst for preparation of this proposal and the dialogue which occurred before and during its preparation.

Suggestions and Recommendations

1 It is possible for the size of the ice bottle used in current packaging systems to be reduced from 1 litre to 500 ml.

2 That better insulated foam box with thicker walls and lid be developed.

3 That further research be conducted into the necessity for and benefits of, holes punched into boxes.

4 That a transport protocol be developed which maintains temperature within boxes of 10^{o}C throughout the transport process. The airlines should be approached to see if utilization of refrigeration units available at the Perth International Freight terminal can be used routinely for packed AVs.

5 That further research be conducted into improved coolant materials, alternative fillers and better insulation, to satisfy both freight requirements of strength, lightness and the physiological conditions required for lobster health.

6 That temperature logging using data loggers become an established practice for live lobster shipments.

7 That the rock lobster industry develop its own glossy information leaflet which explains the live shipment process for western rock lobster and the procedure which should be followed on unpacking, eg placement in seawater, not freshwater. This leaflet should be presented in Japanese, Chinese and Korean, as well as in English and should emphasize the importance of temperature control and stress minimisation during transport.

9 That further physiological work be undertaken to determine the incipient lethal temperature for aerially exposed rock lobster considering environmental conditions during live transport.

10 That further research be undertaken using the Servomex into stress and stressors during aerial exposure.

1 INTRODUCTION

The western rock lobster fishery, over the past five years, has undergone a change in its marketing arrangement in that an increasing proportion of its catch is marketed live. Live product generally attains a higher price than frozen, raw or cooked product. Currently the most successful value adding undertaken by the Australian fishing industry is maintaining seafood for live shipment to export markets overseas.

In 1992/93, 2.3 million kg, out of a total catch of 12.2 million kg, was marketed live, (22.9%) and in 1993/94, 2.8 million kg out of a catch of 11 million kg, (25.5%). The 1993/94 catch was deliberately reduced by governmental management measures, eg 18% pot reduction, increase in escape gap size and other measures, to offer some protection to the rock lobster breeding stock.

The increase in the proportion of the catch being marketed live, from 5% in the 1980's, to 23% in the 90's, occurred rapidly over the last five years and in that time live holding, maintenance and packaging systems have developed largely on an 'ad hoc' basis. A workshop in 'Post Harvest Handling of Live Fish and Shellfish' was convened in Perth, 8/9 July 1993, by Dr M Walker, at that time, of M Walker and Associates P/L, Curtin University of Technology, Aquatic Science Research Unit (CASRU). This workshop was supported by Curtin University of Technology, Aquatic Science Research Unit , the Western Australian Fishing Industry Council (WAFIC) and the Department of Industry Technology and Regional Development, (DITARD). It was well attended by fishing industry representatives, from catching, processing and marketing sectors and by scientific researchers and others. One of the key areas identified by the workshop as worthy of investigation was packaging systems currently used by the western rock lobster industry. Representatives from the National Seafood Centre (NSC) in Brisbane attended the workshop and explained the procedures necessary to access research funds form the NSC.

Improved packaging systems have the capacity to increase survival, extend shelf life, reduce packaging and freight costs and thus increase returns and reduce wastage for the western rock lobster. The research may have application to other species of rock lobsters and to other crustaceans. Each species however, could be expected to have specific optimum packaging requirements.

Dr M Walker and the Rock Lobster and Prawning Association of Australia (RLPA) were successful in 1993 in obtaining a grant from NSC to research packaging systems used by RLPA members and to commence preliminary experimentation which may ultimately lead to improvements in these packaging systems.

Although the program was designed to commence in mid November 1993, the commencement of the 1993/94 western rock lobster season, final approval for the project and therefore funds, were not available until February. This unfortunately meant that the research does not cover the period of the first recruitment of western rock lobsters, known as whites, into the fishery from November - February.

The objectives of the research project were:

1 To survey the packaging systems used with western rock lobster.

2 To determine the range of some physical parameters which may occur to western rock lobsters during transport, in particular temperature, humidity, oxygen, carbon dioxide and ammonia levels.

3 To research into which packaging system best copes with the above physiological parameters.

4 To communicate the results to the fishing industry.

The research was undertaken by Mr Tony Gibson, Executive Chairman, RLPA and two industry fisheries consultants, Mr Phillip Walsh of Food Factotum and Dr Michael Walker of M Walker and Associates P/L. Dr Walker in 1993/94, apart from consulting work, was engaged as Senior Lecturer, Aquatic Science at Curtin University of Technology. In this capacity he utilized research students, both undergraduate and postgraduate, under his direct supervision, to undertake some of the research work. This had an added benefit of training research students and a more rapid communication and assimilation of research results by industry.

This research report outlines in detail the research undertaken in terms of

- a survey of packaging systems used for live western rock lobster
- the determination of the range of physiological parameters which occur to western rock lobster during transport in 3 segments,
    - i factory receival depot to airport
    - ii at the airport
    - iii from factory receival depot to the Japanese customer
- some simulation experimentation using a multichannel temperature logger and boxes packed in various ways, using canned tomatoes (non lobster), which enabled temperatures throughout various parts of the box to be monitored.
- some simulation experimentation to research packaging systems using lobsters packed at processing facilities and monitored using small data loggers included in the box
- some experimental procedures to research physiological limitations regarding temperature, oxygen and relatiive humidity.

The 1993/94 rock lobster season saw 2,793,709 kg of live lobster exported, an increase of 521, 077 kg, an extra 46113 - 52,077 boxes on 1992/93. This data is shown by month and compared with boiled lobster production for the 1992/93 and 1993/94 seasons.

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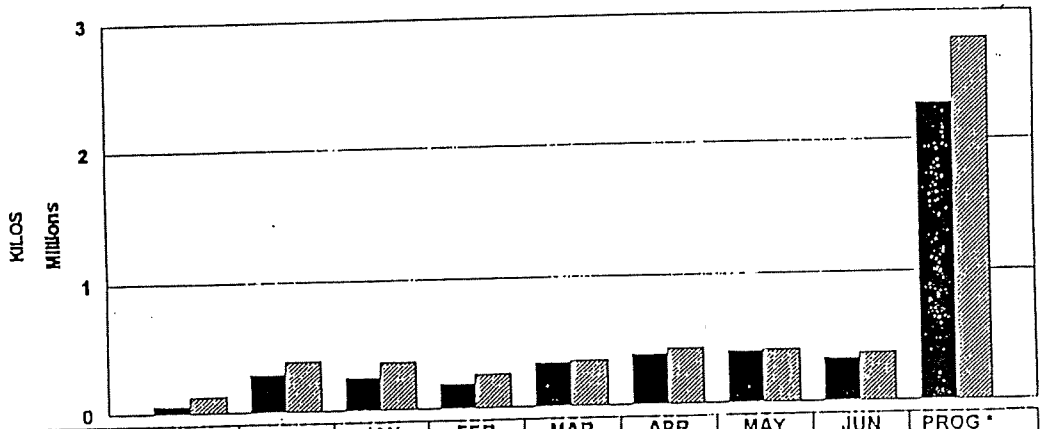
LOBSTER INDUSTRY PRODUCTION FIGURES Page 1

AS AT THE END OF JUNE 1994

LIVE LOBSTER EXPORT PRODUCTION

1992/93 SEASON V 1993/94 SEASON



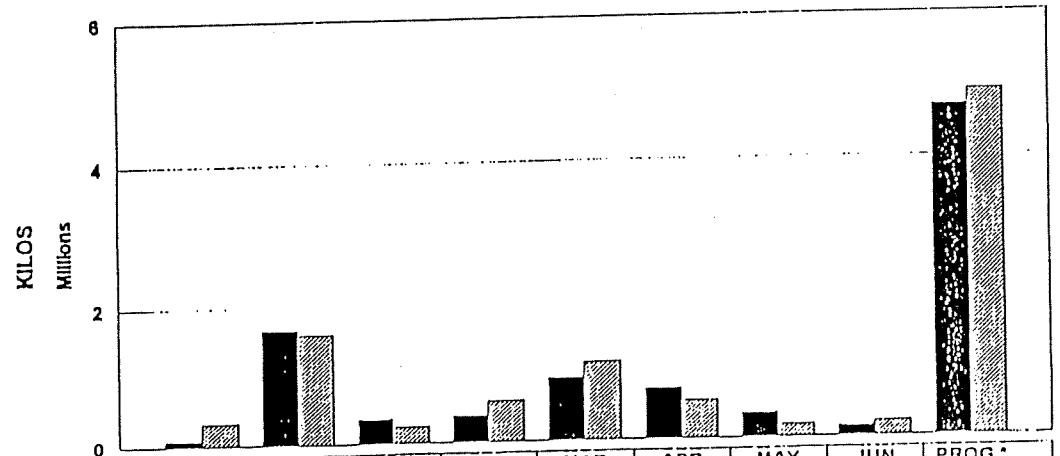
MONTHS	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	PROG *
■ 92/93 SEASON	54,957	294,975	251,585	188,459	344,655	394,007	405,608	338,386	2,272,632
▨ 93/94 SEASON	122,078	394,744	378,743	262,693	358,829	438,681	420,707	379,547	2,793,709

* PROG = PROGRESSIVE TOTAL SEASON TO DATE

Note: No provision made for lobster in holding tanks at month end

BOILED LOBSTER EXPORT PRODUCTION

1992/93 SEASON V 1993/94 SEASON



MONTHS	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	PROG *
■ 92/93 SEASON	81,460	1,671,720	364,060	392,570	920,850	751,100	363,420	139,585	4,690,765
▨ 93/94 SEASON	340,830	1,606,460	242,960	802,960	1,163,440	566,800	183,280	215,000	4,911,790

* PROG = PROGRESSIVE TOTAL SEASON TO DATE

Note: Data compiled by Dept of Fisheries from information provided by lobster processors

Graphs created by Marec Pty Ltd

2. LITERATURE REVIEW

The western rock lobster has been well researched in terms of its life style, ecology, behaviour, population dynamics and some aspects of its physiology (Gray 1992). Very little work, however, has been conducted on the post harvest section of the industry and this is generally the case for similar crustacean species with export value. Witham (1985) reported 4 small experiments with Florida spiny lobster and found that seawater wetted burlap at room temperature was the best packaging material.

Prescott, (1980) outlined South Pacific Commission research in the Solomon Islands with *Panulirus pencillatus*, to determine the best method of live storage and transport in the village situation. At that time there were no facilities for processing or freezing product.

Lisac, (1986), undertook some preliminary lobster post harvest work in the Caribbean and made recommendations in a semi - popular article, as to the necessary requirements of live transport and packaging in general for lobsters. He estimated survival of 1 - 3 days out of seawater, as long as lobsters had been handled, packaged and shipped in a careful manner. Lisac (1986), believed the most important aspects of a live lobster packaging system to be insulation, ability to hold water, light weightedness, ease of handling and ability to withstand pressure. He suggested that packaging materials should be placed into cold storage 1 hour prior to packaging, that no holes should be put in the box (as insulation was most important) and that a coolant such as gel ice be used. Gel ice freezes at below zero and once the temperature reaches ambient absorbs heat from the surrounding environments.

Chhapgar, (1973), gives one of the first descriptions of a live transporting method, not dissimilar to those described by Lisac (1986), however stated that holes in boxes were necessary to allow air to get into the box.

Several others have conducted research on environmental and physiological aspects of other commercial crustaceans species and have made suggestions to assist in the development of better packaging systems. Some of these authors are: Goodrick and Paterson (1992), with Kuruma prawns *Penaeus japonicus*; Paterson et al (1993), with spanner crab *Raina ranina;* and Otwell and Webb with the blue crab *Callinectes sapidus.*

Additionally Witham (1985), worked with *Panulirus argus* and Robertson et al (1984), although concerned with live transport of broodstock prawns for aquaculture, passes comment upon the requirements of live lobster transport.

Goodrick and Paterson (1992) outlined harvest procedures for cultured Kuruma prawns *Penaeus japonicus*, as well as the packaging and packing system of using pre cooled water to 8 - 10^{o}C below pond temperature in a recirculating system without biological filtration. They believed biological filtration to be not necessary as prawns were only in the system for a short period and the rise in ammonia was compensated for by the low temperature and pH of the water used.

Live prawns were placed in 1 kg boxes and then in larger insulated boxes to make up 10 kg lots. Coolants were placed within the larger box outside the 1 kg box to prevent excessive warming. Goodrick et al believed prawns should not be exposed to temperatures below 10°C during transport so that the coolant maintained as stable a temperature as possible between 10 - 17°C. If the coolant was not adequate for the temperature to which the package was exposed, the raised temperature of the prawns caused the metabolic rate to increase and possible death through acidosis. (Paterson, 1993).

Paterson et al (1992), defined the packaging system used for spanner crabs. This was a polystyrene box without holes, padded with sawdust, wood shavings or woodwool. Coolant blocks or sticks were used, rather than ice bottles.

Roberts et al (1984) insisted that temperature maintenance was one of the most important factors when shipping live lobsters. For this to be achieved coolants should be packed with the product in the well insulated shipping container.

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3. SURVEY OF PACKAGING SYSTEMS USED FOR WESTERN ROCK LOBSTER

3.1 Introduction

The western rock lobster has in recent years undergone a transformation in terms of marketing an increasing proportion of its catch live. For the 1993/94 season approximately 25.5 % of the catch 2,793,709 kg, (ie 247,230 boxes) was marketed live. This compares to about 5% of the catch which was the norm some 5 years ago.

The rock lobster processing industry has developed packaging systems largely on a trial and error basis. Collectively the body which represents that sector of the rock lobster industry, the Rock Lobster and Prawning Association of Australia (RLPA), decided it was in the rock lobster industry's best interest, if the industry itself commenced to undertake some post harvest research. It seemed that an appropriate first project was to research the live lobster packaging systems used by its members and to see if they could be improved in terms of improving survival, extending shelf life and be made more cost effective by reducing packaging and freight costs. The first segment of this research was to undertake a survey of the details of the packaging systems used by RLPA members.

3.2 Methodology

Rock Lobster and Prawning Association members were visited during February and March by either of the two consultants engaged in this study. Senior management personnel were asked a variety of questions as to their understanding of the prepackaging methods and packing materials used by their company.

3.3 Results

A summary of each individual interview is given. Interview data has been presented in a manner to attempt to protect the identity of the companies concerned.

3.3.1 Packaging System Used

The procedure followed in general by most processors is as follows:

On receival of lobsters from fisherman they are removed from lug baskets and immediately sorted according to condition and strength. Strong animals with most appendages attached are then placed into flow through or recirculating seawater systems by size/grade, for up to 3 days (sometimes more for large orders, freight space, weather etc).

Prior to shipment,generally 2 hours prior to transport to airport, they are placed into chilled sea water for up to five minutes and then packed into foam eskies which contain a layer of wood shavings and which has between 2 and 4 holes punched into its ends. Depending upon size, up to 10 lobsters are packed per layer. A plastic bottle containing frozen salt or freshwater and wrapped in

newspaper or butchers paper, is placed into the centre of the box and covered with further shavings. A second layer of lobsters is then added to the box and covered with more wood shavings. The lid of the box is then placed onto this box and taped into place both around the lid and the box. The box is usually overfilled with woodshavings and packed tight to keep lobsters immobilized. Boxes are then placed into a cool area or on a truck ready for transport to the airport. In some cases a cardboard sleeve is placed over the box. Mostly, however, a sticker or printed box is used.

3.2.2 Industry opinions regarding their packaging system

Industry opinions may be summarized in terms of the following:

- strengths
- weaknesses
- what we don't know and the problems
- tracking shipments and mortality
- the most important things

Strengths of the current packaging system

- it works
- current knowledge and expertise
- reduced cost of packaging materials with time.

Weaknesses of the current packaging system

- the high cost of packaging system
- extra weight of packaging materials
- general lack of control over the packaging and transport methods
- lack of research and knowledge
- 'no responsibility' attitude of the airlines (shipments left at airport, put in wrong place on aircraft, stored with wrong materials ie lamb at $0^{o}C$ - live lobster transport is now a big business for airlines and they should be prepared to tell the industry when not to send).

What we don't know and the perceived problems.

- Do we need a spacer between layers of lobster in boxes?
- What is the thermal efficiency of an esky?
- What is the actual effect of the water bottle? does it cool or cause condensation and so Keep up the humidity?
- Do we need a water bottle if weather is cold?
- What is the insulation capacity of the wood shavings?
- How does one judge the health of a rock lobster?
- The mortalities are highest around February at moult time. Why and how may they be reduced?
- High water temperature in holding tanks is a problem in summer.
- Freshwater and dirty water intakes are a problem in winter.

- Current airline handling procedures allow boxes to spend too much time at airport, often left in the sun, often thrown around, or placed in wrong part of the aircraft.

Tracking shipments and mortality

- never track could be used for claims
- we only know when there is a problem. The marketing people believe that problems occurred due always to packing rather than the general health of the animals
- most customers keep records. We ask each shipment survival, short wt, general condition, time tank to tank.
- Japanese keep records and give reports. Taiwan, China and Hong Kong do not.
- You can create your own mortality depending upon the condition of the animal
- mortality assumed to be 3%. Trading terms exclude mortality claims unless large numbers. Suspicion that these claims coincide with price problems rather mortality.

Most important things

- health of the lobster upon receival in processing premises
- correct selection of the animal for shipment
- most damage to the lobster occurs during transport from boat to factory
- increased mortality during the moult stage of lobster
- immobilization of the lobster in the box
- transit time, especially in aircraft
- time left in sun especially at airport
- ambient temperatures at airports
- handling at the airport
- conditions in the hold of the aircraft and the other cargo being carried, eg dried flowers, vegetables, frozen food.

3.4 Summary and Conclusions

The packaging system used by rock lobster processing companies was found to be basically the same, in insulated boxes with 2,4 ,or 8 holes, pencil size in diameter, punched into the ends and containing 8, 9 or 10 kg of live lobster, (depending upon customer requirements).
The packaging material used was wood shavings at room temperature, the texture and fineness of which varied. Most processors had used wood wool in the past, which was a much cleaner and cheaper material requiring no washing of lobsters on unpacking. For some reason Japanese customers had perceived that wood wool from WA was causing mortality and had stipulated that it was no longer to be used. This was somewhat strange as they still accept New Zealand lobsters packed in wood wool.
A water bottle containing 500 ml or 1 litre frozen fresh or saltwater at a variety of temperatures (from -5^{o} to -35^{o}oC) was added to the centre or top of the box. It is presumed that a seawater bottle or high salt bottle would have a different rate of change in the esky, than a fresh water (non salt) ice bottle.

The box was overpacked with woodshavings and the lid forced on and taped around the join. In some cases, tape was run over the box, (banding) causing some disturbance to its contents. In other cases banding was not used. Cardboard outers were used in some cases, in others they had been abandoned to reduce cost and or waste disposal problems at the customer end. Where outers were not used printed lids or stickers identified the brand name.

The major differences in the packaging system were the purging procedures. Most processors simply sorted and selected the strongest lobsters and placed them into flow through systems for about 3 days or more, until pack out. Others, after one day, removed lobsters from flow through systems and placed them into recirculating systems on the premises or at another location. Processors using flow through systems placed lobsters into chilled water at around 5^{o}C, for periods of up to 5 minutes to immobilize them, whilst those using recirculating systems had the capacity to reduce the temperature gradually to about 11^{o}C for pack out.

Lobsters were packed into boxes and transported to the airport in refrigerated or non refrigerated insulated trucks. The time of transport varied depending upon location. For the furthest location from the airport , ie Geraldton, pack out was up to 8 hours prior to departure. Transport conditions will be discussed further in the next chapter.

The processing industry generally believed that their current system was satisfactory. It had developed and changed with time. They acknowledged that with research and further knowledge, it may be able to be improved. The major concerns were for factors outside their control, such as transport of animals from boat to factory, handling and storage at the airport, location within the aircraft hold and temperature fluctuations at airports. These factors were all beyond their control and were mostly the responsibility of the airlines. The industry, without exception, believed that the live transport business was a major business for the airlines and that the time had come for the airlines to treat the product, and them, better rather than having a 'no responsibility taken' attitude.

The attitude of the industry regarding monitoring of mortality in transport varied from not doing so, to tracking every shipment. They believed that Japanese customers mostly were interested, but others, ie Taiwan, China and Hong Kong were not. In general, industry believed that marketing personnel unfairly blamed mortality problems upon them rather than upon the health of the animal prior to arrival at the factory or to transport problems. It appeared that most processors sold live product with a no claims clause up to 5% mortality, thus had no interest or were not aware of mortalities below 5%.

PACKAGING SYSTEM SURVEY SHEET

Prepurging details	
Purging details	
No of live tanks used	*Many*
Purging time	
Recirculating or flow through system	*Flow through*
Prepacking details	
Dipping time	
Packaging details	
Foam esky	*9 or 10 kg, Gross wt 13.5 kg*
No of holes	*4 holes each corner pencil size*
Water bottle	*1 litre frozen salt water -35^{o}C*
Sleeve used	*No, adhesive label*
Materials	*Dry wood shavings*
Time	*45 cartons / hr*
Comments	*Currently putting denitrifying bacteria on shavings*
Transport details	
Time	
Mortality Details	
Percentage	*1%*
Trading terms	
Comments	*Most important thing condition of lobster in first place. varies with time of year*
Modifications to Packaging Systems	
Comments	*Has been modified with time*

Comments or Criticisms of Packaging Systems

Happy with system. Ask customers to keep records Japanese do, Taiwanese do not.

PACKAGING SYSTEM SURVEY SHEET

Prepurging details	
Purging details	
No of live tanks used	
Purging time	*Overnight flow thru + 1-2 days recirculating*
Recirculating or flow through system	*Both*
Comments	*Concerned about the lack of control of flow through system led to a mixture of flow thru and recirculating. O2 depletion in warmer months caused mortality.*
Prepacking details	
Dipping time	
Packaging details	
Foam esky	*10 kg,*
No of holes	*1 pencil either end*
Water bottle	*1 litre frozen salt water*
Sleeve used	*No, sticker*
Materials	*Wood wool 1992/93* *Dry wood shavings 1993/94*
Time	*10 pm pack out for 6 am flight*
Comments	*Trials showed high mortality with no holes*
Transport details	
Time	*13 hrs Taiwan 30 hours Japan*
Mortality Details	
Percentage	*2-3%*
Trading terms	
Comments	*Higher mortality than 2-3% after 48 hours*

Modifications to Packaging Systems
Comments *Changed from wood wool which customers preferred as no wasting on unpacking required to dry wood shavings because of perceived mortality problems by customer*

Comments or Criticisms of Packaging Systems

Poly boxes not strong enough
Critical of airlines handling and throwing boxes

PACKAGING SYSTEM SURVEY SHEET

Prepurging details	*On receival graded for strength, strong animals transport to live tanks*
Purging details	
No of live tanks used	8
Purging time	*3 days*
Recirculating or flow through system	*Flow thru*
Comments	*1-2 days purging time leads to a higher risk of mortality*
Prepacking details	*Placed in lug baskets, drained weighed and rechecked for strength before dipping*
Dipping time	
Packaging details	
Foam esky	*8 kg, net*
No of holes	*12 pencil holes both ends (4)*
Water bottle	
Sleeve used	*Yes*
Materials	*Clean wood shavings or sawdust*
Time	*2 hours,varies with volume*
Comments	*Previously used paper as client requirement. Wet paper or packaging material increases mortality*
Transport details	
Time	*1 hr to airport*
Mortality Details	
Percentage	*3% assumed*
Trading terms	*Exclude mortality unless large numbers*
Comments	*Suspect mortality claim often coincide with price.problems rather than mortality*

Modifications to Packaging Systems
Comments *System has been modified over the years*

Comments or Criticisms of Packaging Systems
Happy with system however any improvement or suggestions would be most welcome

PACKAGING SYSTEM SURVEY SHEET

Prepurging details	*Graded for quality and loaded into open seawater tanks*
Purging details	*Placed into flow thru tanks 2 days later moved to recirculating tanks*
No of live tanks used	*Many*
Purging time	*2 days flow thru*
Recirculating or flow through system	*Flow thru and recirculating*
Comments	*1-2 days purging time leads to a higher risk of mortality*
Prepacking details	*Product chilled 10-12^{o}C 1 day prior to packing*
Dipping time	*Chill overnight*
Packaging details	
Foam esky	*8 ,9,10 kg, to customer's needs*
No of holes	*2 holes either corner (4)*
Water bottle	*1 litre ice bottle*
Sleeve used	
Materials	*wood shavings*
Time	
Comments	
Transport details	
Time	
Mortality Details	
Percentage	*2-3 % at less than 5%*
Trading terms	*No claims at less than 5%*
Comments	*Concerned at airline handling. transit delays mortality reason assumed . 1 time container topped with lamb at 0^{o}C*

Modifications to Packaging Systems
Comments *Yes*

Comments or Criticisms of Packaging Systems

PACKAGING SYSTEM SURVEY SHEET

Prepurging details	
Purging details	
No of live tanks used	*Many*
Purging time	
Recirculating or flow through system	*Both, Going to recirculating*
Comments	*Use fish heads to create the bacteria*
Prepacking details	
Dipping time	*Chill rapidly*
Packaging details	
Foam esky	
No of holes	*10 holes in box, 5 holes either end*
Water bottle	*frozen iced seawater, wrapped in newspaper*
Sleeve used	*Yes*
Materials	*Dry shavings , the finer the better*
Time	*6 hours prior to airport departure*
Comments	*Reduce the time at the airport in Perth*
Transport details	
Time	
Mortality Details	
Percentage	
Trading terms	
Comments	

Modifications to Packaging Systems
Comments *Yes, have tried many things, holes, no holes. Attribute a list of our success to the packaging*

Comments or Criticisms of Packaging Systems
Marketing division track shipments. Problems here if water temperature high. Immobilization is the key. Weakness lack of control. Key is quality and judging the health of the animal

PACKAGING SYSTEM SURVEY SHEET

Prepurging details	
Purging details	
No of live tanks used	*Many*
Purging time	
Recirculating or flow through system	*Recirculating and flow thru*
Comments	*Building a new recirculating system*
Prepacking details	
Dipping time	*Want to bring lobsters down slowly to 11oC*
Packaging details	
Foam esky	*Yes*
No of holes	*2 small holes*
Water bottle	*1 litre - 35oC 3 layers of butchers paper wrapped Ice bottle centre on top*
Sleeve used	*No ,sticker*
Materials	*Pine shavings , the finer the better*
Time	
Comments	*Tape lids no strap. 500 ml for short trips Wood wool excellent material*
Transport details	
Time	
Mortality Details	
Percentage	
Trading terms	
Comments	*Receive information*

Modifications to Packaging Systems
Comments *Yes, all the time.*

Comments or Criticisms of Packaging Systems
System could be improved, Weight the problem. Ice bottle not the problem. It is the ambient temperatures at the airports. Receive reports all the time water temp, where mortality in carton, limb loss.

PACKAGING SYSTEM SURVEY SHEET

Prepurging details	
Purging details	
No of live tanks used	
Purging time	
Recirculating or flow through system	
Comments	
Prepacking details	
Dipping time	
Packaging details	
Foam esky	*printed box 8 kg net*
No of holes	*hole either corner*
Water bottle	*1 litre - 20oC*
Sleeve used	*No*
Materials	*Buzzer chips - sieve them, 2 sheets of paper in the centre*
Time	
Comments	*Freight a big cost*
Transport details	
Time	
Mortality Details	
Percentage	
Trading terms	
Comments	*2 claims in 7 years*

Modifications to Packaging Systems
Comments *Used to put a plastic bag over the bottle and seal it. Now do not..*

Comments or Criticisms of Packaging Systems
Do not track shipments. Would like one tracked.

PACKAGING SYSTEM SURVEY SHEET

Prepurging details	
Purging details	
No of live tanks used	*Many*
Purging time	*Several days*
Recirculating or flow through system	*Flow thru*
Comments	*How do you judge a healthy lobster?*
Prepacking details	
Dipping time	
Packaging details	
Foam esky	*8 kg,9 kg soon*
No of holes	*1 each corner*
Water bottle	*1 litre ice bottle centre tap water*
Sleeve used	*No*
Materials	*Wood shavings*
Time	
Comments	*Have experimented with 500ml, 750 ml bottles*
Transport details	
Time	*Greater than 36 hrs often* *5 1/2 hrs to airport* *Monitor time tank to client tank.*
Mortality Details	
Percentage	
Trading terms	
Comments	*Mortality varies with lobster condition. Can create the mortality you want.*

Modifications to Packaging Systems
Comments *Yes. Have tried and tested many things over the years. The system has changed and is still changing. No sleeve and no straps. Materials now cleaner. Packaging materials to 2 kg net.*

Comments or Criticisms of Packaging Systems
Japanese monitor mortality. Taiwan, China, Hong Kong, no. If you ask they give you a mortality. If you don't they don't. So why ask? Marketing people like to believe its the packing not the lobsters original health.

PACKAGING SYSTEM SURVEY SHEET

Prepurging details	*Inspect, sort. Strongest kept, rest cooked.*
Purging details	
No of live tanks used	*Many*
Purging time	*Several days*
Recirculating or flow through system	*Flow thru*
Comments	
Prepacking details	
Dipping time	*3-5 minutes cold water*
Packaging details	
Foam esky	*9 kg (Gross 12.5 -13)*
No of holes	*2 each end near top near top*
Water bottle	*1 litre Ice water bottle*
Sleeve used	*Yes*
Materials	*Straw or wood shavings*
Time	
Comments	
Transport details	*Refrigerated trucks to airport*
Time	*1-5 hours*
Mortality Details	
Percentage	*1-1.5%*
Trading terms	
Comments	

Modifications to Packaging Systems
Comments *Many over the years*

Comments or Criticisms of Packaging Systems
Strengths, 99% survival
Weaknesses extra weight, attitude of airlines (no responsibility taken). Should be able to tell when not to send.

4 RANGE OF PHYSIOLOGICAL PARAMETERS WHICH MAY OCCUR TO WESTERN ROCK LOBSTERS DURING TRANSPORT

4.1 Introduction

The physiological stressors to which western rock lobster may be exposed during transport from processing factory to the customer at some overseas destinations are beyond the control of the processor or the the rock lobster industry and largely in the hands of the transport industries, airlines and trucking companies. Packaging systems have evolved largely on an 'ad hoc' basis at the whims of the processsor, customer or because of stipulations of the transport industries. They have not considered to any large degree the physiological requirements of the rock lobster nor its response to stressors such as temperature, humidity, light, pressure, etc.

These stressors are largely undocumented in the literature and are generally poorly understood by the rock lobster industry. This study represents a preliminary attempt to obtain real situation data concerning them.

4.2 Materials and Methods

Small commercially produced data loggers weighing from 20-26 gms and of dimensions (32mm X 45mm X 15mm) - (49mm X 46mm X 25mm) for temperature(3), relative humidity (1), and pressure (1) were obtained. These loggers are commercially produced in Australia and are launched and store information, which was read using accompanying software via Mac or PC compatible computers (Further commercial information concerning these loggers is given in Appendices.

Loggers were activated using a PC computer at processing facilities and were placed into a box(es) of rock lobsters packed for live export either by processing or research staff. Loggers were set for a duration of hours which depended upon length of anticipated shipment journey. This varied from 8 hours to 36 hours. The experimentation duration was of two basic sorts tracking from processing facility to either arrival at airport, or export customers' facility overseas.

4.2.1 Factory Receival to Airport

A polystyrene box was packed with 18 western rock lobsters (corals) in Geraldton at 2000 hrs, 22.3.94 by processing and research staff. 3 temperature loggers were placed in the box, RHS top cnr (no 2), LHS top cnr (no 3) and in centre of box adjacent to water bottles (no 1). Additionally a humidity and pressure logger were added to the top of box, top RHS, bottom cnr and top LHS bottom cnr. This box was placed directly on an insulated refrigerated truck for transport to Perth. The truck transported a shipment of live lobster to Perth Airport, arriving Perth at about 0700. When other boxes were prepared for loading, the box was moved and placed in the shade 0090 - 0930 and later removed to an air conditioned office until about 1050. At 1050 hrs, the box was transported on an air conditioned car to a tunnel house aquaculture facility for release into tanks.

4.2.2 Airport

Several visits were made to the airport to watch the process of arrival of lobsters, their unpacking from transport trucks, packing into AV containers and ultimate loading into an aircraft hold. Notes and photographs were taken.

4.2.3 Factory Receival Depot to Japanese Customer

A shipment of live lobsters was tracked from a lobster receival depot processing facility approximately 1 1/2 hour transport time form Perth, to receipt by a regular Japanese customer out of Tokyo. 3 temperature and one relative humidity and one pressure data logger was added to one box within the shipment. Data loggers were placed one in each corner at the top of the box. One temperature logger was placed in the middle of the box adjacent to the one kg ice bottle. The box was packed by factory personnel and accompanied thereafter by research personnel until its arrival in Narita airport out of Tokyo.

4.3 Results and Discussion - Transport

4.3.1 Factory Receival to Airport.

Figures show the temperature regime in the box during transport and handling and also relative humidity and pressure.

Temperature for the logger adjacent to the water bottle ranged from 38^{o} - 3^{o}C. The presence of the water bottle rapidly reduced the temperature of the adjacent logger to 3 - 4^{o}C until arrival at the airport when temperature increased to about 10^{o}C and further to 32^{o}C, the air temperature at that time.

The loggers) in the top corners of the box had their temperature reduced from 30^{o}c to about 17^{o}C on arrival at the airport, when temperatures increased to air temperature. Relative humidity was reduced in the box from 80% to 70% and maintained between 71 and 75% until arrival at the airport when it increased.

Pressure in the box commenced at 1035 mbar, increased to 1040 mbar and during transport to the airport, decreased from 1030 to 1000 and increased back to 1030. It would appear that the refrigeration unit in the truck had the capacity to reduce pressure.

These results give some experience of the parameters of temperature, humidity and pressure. They also show that as far as temperature is concerned the ice bottle only effects the area adjacent to it as it has little obvious effect upon the other 2 temperature loggers which were located on the top of the box. The ice bottle could, however, effect the relative humidity in the box.

4.3.2 Airport

The procedures at the airport as observed were as follows.
Live lobsters were unpacked from delivery vehicles which were generally insulated refrigerated trucks with or without refrigeration systems operating. Airport staff unloaded boxes of live lobsters on arrival or at time periods thereafter, depending upon their work schedule at the time and/or aircraft departure times. Boxes were either unloaded onto pallets or into AV containers. This procedure was watched by delivery truck drivers and supervised by freight forwarding agents, who attached stickers onto each box. Commercial specifications were written on stickers, eg airline, weigh bill, destination, consignee and consignor.

Loaded AV containers or pallets were stored inside the freight terminal. Approximately 1 hour prior to the flight they were placed on to trailers and towed out to the tarmac where they were loaded onto the aircraft.

Generally lobster boxes were carefully loaded onto AV containers or onto pallets. On several occasions live lobster boxes were thrown from one handler to another. In spite of there being several insulated refrigerated units within the freight terminal. on no occasion were they observed to be used for live lobsters. The freight terminal was a large uninsulated building.

Examination of Figures which plot temperature logging data, shows that the temperature within lobster boxes increases on arrival at the airport and continues to do so. Relative humidity and pressure do so also.

4.3.3 Factory Receival Depot to Japanese Customer

The pack out of the live lobster shipment began at 1030 hrs on Sunday 10.4.94. The lobsters were taken from a flow through seawater system, the water temperature of which was 11.1^{o}C. The air temperature at 1030 hrs was 24.8^{o}C. 19 lobsters were packed into a box which had 2 holes, one in each diagonal corner of the box, with wood shavings (temperature 22.9^{o}C), along with a 1kg ice bottle. Lobsters had previously been immobilized by immersion in cold water at 8.1^{o}C. After packing boxes were stored in a cool place awaiting the arrival of a truck from further up the coast. The truck arrived at 1245, was loaded with lobster boxes and left at 1300. The air temperature inside the truck prior to departure was 19.4^{o}C. The truck was followed by researchers to the airport.

The truck arrived at the airport at 1440 hrs. Being a Sunday there was no-one around and the truck waited until 1615 to be unloaded. The air temperature in the sun was 36.5^{o}C and in the shade 29.8^{o}C. Loading into an AV container was completed by 1635 and was moved inside to the load area and out of the sun (1645). The air temp inside was 27.8^{o}C and outside 31^{o}C. The loading procedure by the airline handler was a little rougher than had been generally observed before, with many boxes being thrown and caught from handler to handler rather than handed. At 1905 hrs the AV container located inside the loading area which was not full, was partially occupied with product from another processor. The air temperature then was 22^{o}C. At 1935 hrs the AV units were moved on trailers out onto the tarmac and loaded onto

the aircraft. The cargo doors of the aircraft were closed at 2205 and the aircraft took off at 2230 accompanied by a researcher.

The AV container was loaded onto position 43 towards the rear to the aircraft. The other freight onboard the 707 passenger aircraft, was 700 kg of fresh flowers, 1,757.18 kg of chilled pork and 100 kg of wine samples. Apart from the consignment of 754 kg of live lobsters (60 boxes) which were being tracked there, were onboard the aircraft another 705 boxes of live lobsters weighing 8059 kg. (Appendix 10).

The Perth - Tokyo flight distance was 7,917 km. Arrival time was scheduled to be (0900 Perth time) 0800 Tokyo time and the air temperature to be 9^{o}C.

During the flight ,the pilot and co-pilot were visited in the aircraft cockpit and asked some questions relevant to conditions in the cargo hold. The pilots stated that the ground personnel select the temperature of the cargo hold(s), and that there were only two temperature selections in the hold, - cold and warm. On the warm setting a heat valve opened up at 7-11^{o}C, until temperature reached 18C, when the valve shut off and the temperature returned to 7C. This setting was used if live vertebrate animals were onboard (eg dogs) If this valve malfunctioned the temperature could reach as high as 32^{o}C. The temperature outside when speaking to the pilots was - 48C. If no live animals were present, as for this flight, the temperature was maintained at 7^{o}C. There was, however, no equipment aboard the aircraft which logged the temperature of the cargo holds. The relative humidity in the hold was low as zero.

Upon arrival in Tokyo the AV container was unloaded at 0903 Tokyo time. The air temperature was 9^{o}C. It was not possible to observe the unloading procedure, customs, etc.

The shipment of live lobsters containing the monitored box arrived at a wholesalers premises. This wholesaler had a network to the western side of Tokyo and had been in the business for 6 years. They had their own recirculating seawater tanks and had in stock, NZ lobster, *Jasus edwardsii,* western rock lobster and *Homarus americanus*.

The shipment was unpacked at 1325, the temperature being 13.2^{o}C. 5 boxes were checked in detail. If problems were found, more boxes would be checked. Lobsters were washed and put into tanks for re-examination and sale, after 24 hours.

The water bottle in the box of lobsters containing the data loggers when unpacked was at 13^{o}C and had 1cm of water around the ice block. The box was damp, apparently a bad sign, and contained two dead lobsters of the 19 unpacked. One of these dead lobsters had had its antennae pulled off. The removed antennae had a 4 square cm of congealed blood around its proximal end.

The Japanese wholesaler had 6 years data consisting of every shipment received. This data recorded mortality, state of ice bottle, limb loss, antennae loss. He stated that usually the mortality was 3-5% and up to 8-10% after 24 hours. The least mortality was 1%. Up to 5% mortality on unpacking was accepted without comment. Beyond that the agent would be informed. Two

examples of the data sheets used by the wholesaler for the sampled boxes are appended. The data sheet recorded number of lobsters, box weight as recorded on box (B), box weight on receival, mortality, limb loss and antennae loss. Conditions in the wholesalers' tanks were also recorded routinely, in this case water temperature, salinity, pH and ammonia levels. The overall mortality after 24 hours was also recorded, as was the mortality on unpacking the shipment. This particular wholesaler had a stack of data sheets 20 cm high, a large number in excess of 3,500 shipments and rightfully claimed to have considerable knowledge of live lobster transport and condition on arrival.

4.4 Summary and Conclusions

Hobo data loggers proved to be compact and efficient means of logging temperature, relative humidity and pressure within packed live lobster box(es).

They were utilized to log temperature, relative humidity and pressure conditions within a packed live lobster box from Geraldton to the airport and from a lobster port approximately 1 1/2 hour from Perth, to receipt by a Japanese wholesaler out of Tokyo, some 28 hours later.

Data loggers showed that conditions within the box were largely influenced by the external environmental conditions be they within a factory, a refrigerated van during transport, in the cargo loading bay area at the airport, on the tarmac, or within the cargo hold of an aircraft. The foam esky type box used for live lobster transport and its contents was found to be a relatively poor insulator.

The ice bottle placed within the centre of the box reduced the temperature for lobsters in near proximity, but had little effect upon those in the top layers. It, however, may play a part in terms of maintaining a higher relative humidity. This requires investigation.

The extremes of temperature to which lobsters were exposed during transport were from 3^{o}C - 38^{o}C and relative humidity from 100 to 71%. Pressure varied from 1000 - 1040 mbar.

The tracking of a box of live lobsters to Japan revealed a mortality of 2 out of 19 lobsters, one of which had died from having one of its antennae torn off. The Japanese wholesaler to whom the product was shipped was found to be well informed in terms of the conditions in which the lobsters arrived and the effects of the packaging and shipping processes. He had documented the condition upon arrival of at least 5 boxes from every shipment he had received in the last 6 years and thus had accumulated a large amount of arrival condition data. As far as this wholesaler was concerned, on arrival mortalities in excess of 5% were reported to his agent.

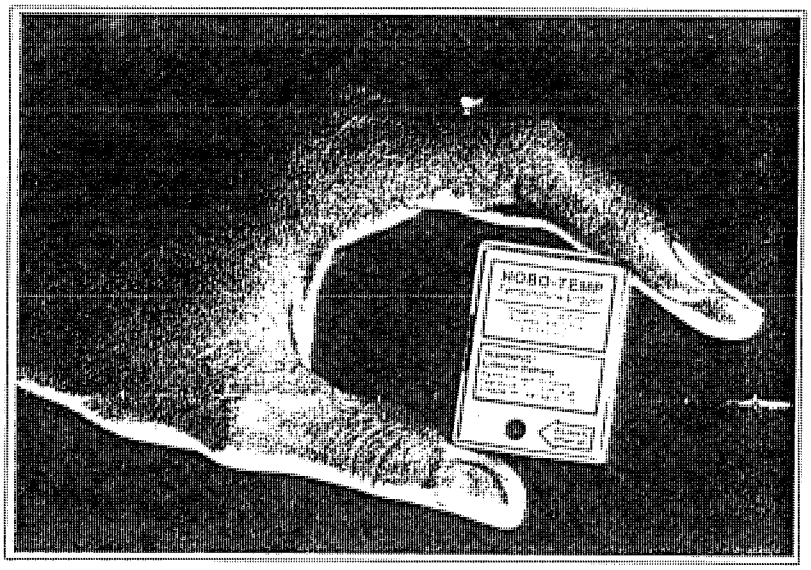
It was ascertained that during the shipping procedure, airline cargo staff did not always handle the live lobster with care, occasionally throwing boxes from one to another, rather than passing from hand to hand. Rough handling of boxes may cause damage to lobsters in the vicinity of the heavy 1litre ice bottle and to those with antennae sticking out of the box, a relatively common occurrence. It was also determined that there was only a minimal amount of temperature control within air craft cargo holds. The temperature range to be

used was predetermined by ground staff prior to departure, depending upon the contents of the cargo hold. If frozen product was in the hold low temperatures were maintained and for live animals, eg dogs, higher temperatures. The cargo hold usually was maintained from 7 to 18^{o}C. If low temperatures required the heating valve was not turned on by the pilot and the hold temperature was maintained around 7^{o}C. If higher temperatures were required the heating system was turned on until temperature reached 18C when it automatically shut off until the temperature reached in the vicinity of 7 - 11^{o}C. If the valve malfunctioned and would not close off it was possible for the temperature to reach 32C. Relative humidity in the hold was maintained at zero and is pressurised at a constant level.

The environmental parameters of temperature, relative humidity and pressure and their variation during the shipping / transport processing from packing facility to export customer determined in this study provide important background data for simulation experimentation later in this research and by others in the future. They were, previous to this study, largely unknown.

HDL DATA LOGGERS by Hobo™

YOU CAN AFFORD



WHETHER YOU GROW - PROCESS - SHIP OR STORE

The REMARKABLE HOBO data logger by HDL gets you the information you require at a price you can afford.

The HOBO family of data loggers by HDL include:
• Temperature • Humidity • Pressure
• Light Intensity • Salinity • AMPS • Volt's

HOBO DATA LOGGERS by HDL are self contained and do not require connection to any other equipment when logging.

HOBO'S by HDL are MAC or PC Compatible and work with either DOS or Windows.

HOBO'S EASY TO USE software enables you to launch and read the information stored. Then Save - Display - Print - Plot - Expand - Edit - Export.

The easiest way to try out a Hobo data logger is to order a starter kit from HDL. In it you will find everything you need to start gathering data.

BATTERY POWERED
Hobo's battery lasts up to 2 years

NON VOLATILE MEMORY
Even if the battery is removed or the Hobo damaged your data is safe

DEPLOY UP TO 360 DAYS
Choose from 15 minutes to 1 year
Intervals from .5 second to 4.8 hours

RE-USABLE
Hobo's are reusable as many times as you like which makes them very cost effective

TRACKING HOBO'S
Each Hobo has a unique electronic serial number which means easy identification and tracking of several HOBO's

APPLICATIONS INCLUDE
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HDL - Hastings Data Loggers

Hobo Temp & RH

HOBO Temp - INT

Description

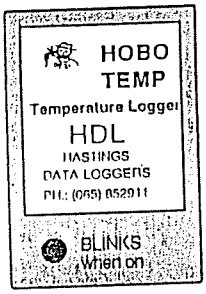
HOBO - TEMP logs air temperature. Data can be shown in Centigrade or Fahrenheit.

Sensor
High precision thermistor.
Mounted internally

Accuracy
+/- 0.2 C

Time Constant
10 seconds in air .

Ranges	Resolution
-39 to +75 C	.35 C
-37 to + 46C	.26 C
-5 to + 37 C	.16 C



Size: 32mm*45mm*15mm
Weight - 20 g

HOBO Temp - XT

Description

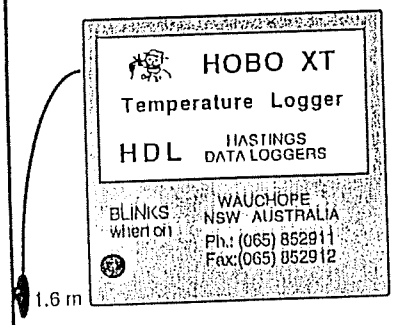
HOBO XT logs temperature with an externally mounted sensor in air or liquids.

Sensor
High precision thermistor.
At the end of a 1.6m flexible lead

Accuracy
+/- 0.2 C

Time Constant
1 second in liquid.

Ranges	Resolution
-39 to +123 C	0.35 C
-37 to +46 C	0.26 C
-5 to +37 C	0.16 C



Size: 49mm*46mm*15mm
Weight - 28g

HOBO - RH

Description

HOBO RH measures and logs relative humidity data.

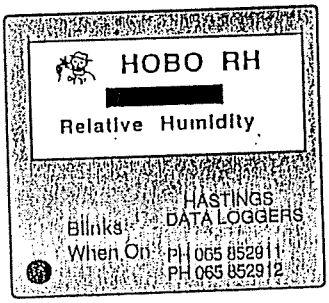
Sensor
Thin film polymer.

Accuracy
+/- 5% RH from +5C to +45C

Response Time
3 minutes

Range

0 to 100% RH non-condensing.



Size: 49mm*46mm*25mm
Weight - 26g

Common Specifications

Recordling Time User seletable 15 minutes to 360 days **Intervals** from .5 seconds to 4.8 Hours

Processor Low power CMOS, with 8-bit A-D converter **Memory** 1800 readings In non volatile memory.

Interface Inbuilt RS 232 driver to serial communications port (D9 or D25 with adaptor)

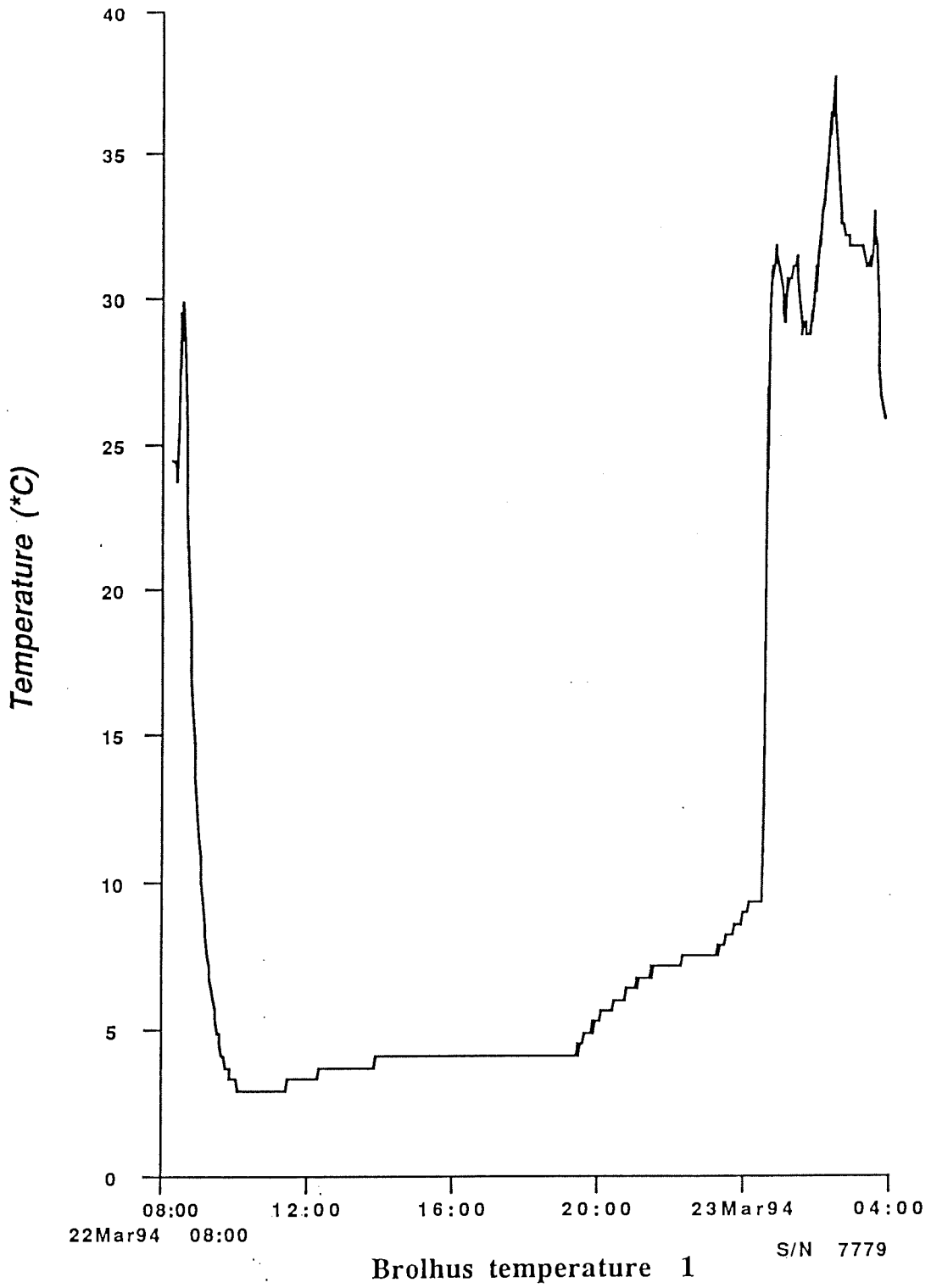
Operating Envlroment 39 to+75C for Logger **Case** Lightweight Rigid Plastic

Host Computer PC Dos Windows or MAC **Battery** Single 3.6V Lithium user replaceable 3.6V

Software **Simple** Launch and Readout **Automatic** Graph of recorded data **Expand** Any section of the plot
Export To Excell and Lotus 123 etc. **Cut and Paste** to reports letters etc **Print** Send any selection to printer

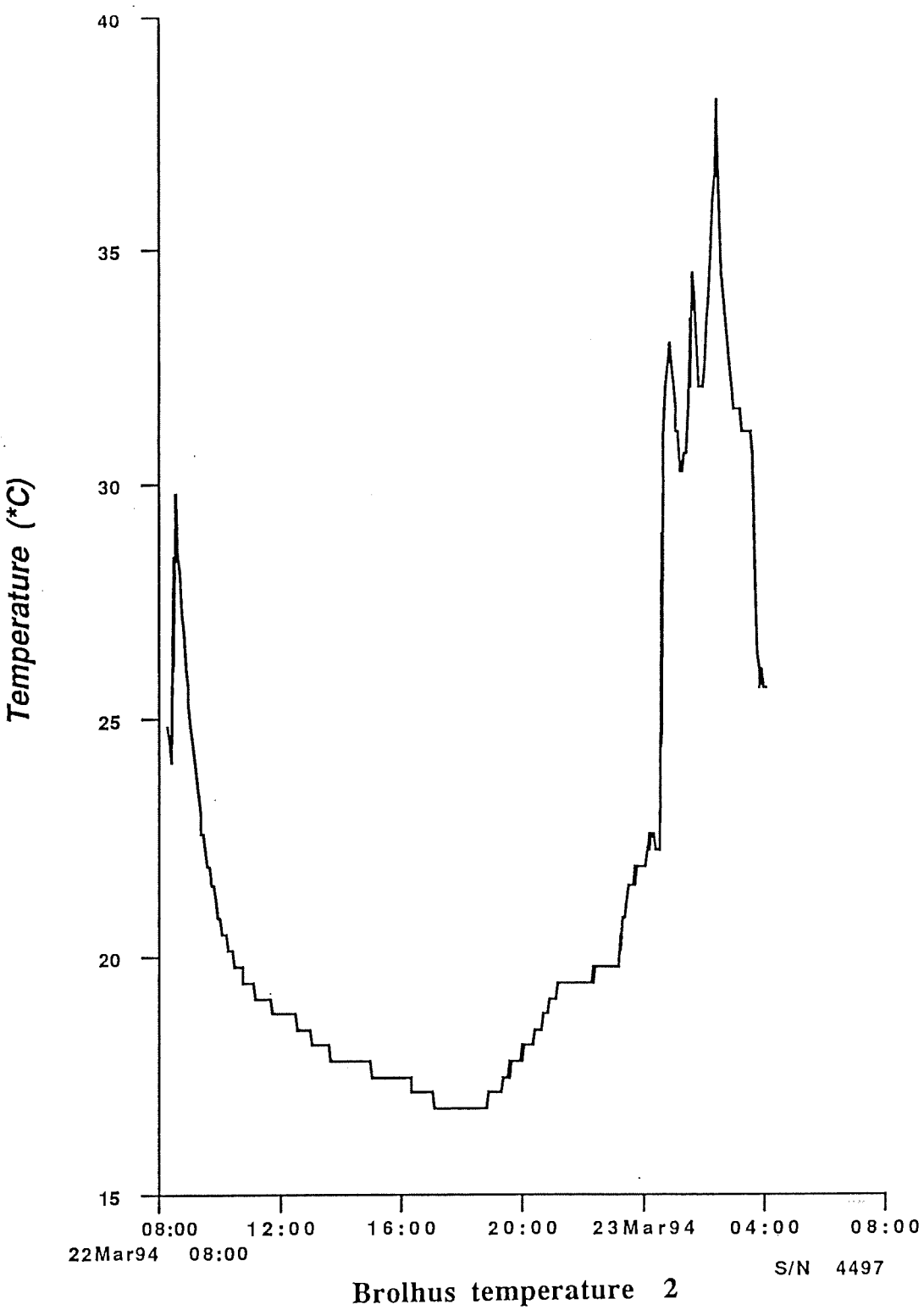
HDL

35 Lake Innes Drive, Wauchope 2446 Australia
TEL 065 852911 065 852912



A polystyrene box was packed with 18 coral lobsters at 8.00pm, 22nd March 1994, in Geraldton. The boxes were placed directly into the truck.

At approximately 8.00 am on the 23rd March 1994, the box was removed from a refrigerated truck, upon which it was left under a large veranda until approximately 9.00 - 9.30 am. At this time it was moved across the road to an air-conditioned office. It was removed from there and placed in a car at 10.50am. It stayed in the car which was air-conditioned (most of the time) until 12.00 noon where it was taken into the Aquaculture tunnel-house and the lobsters released into tanks at 12.10 pm.



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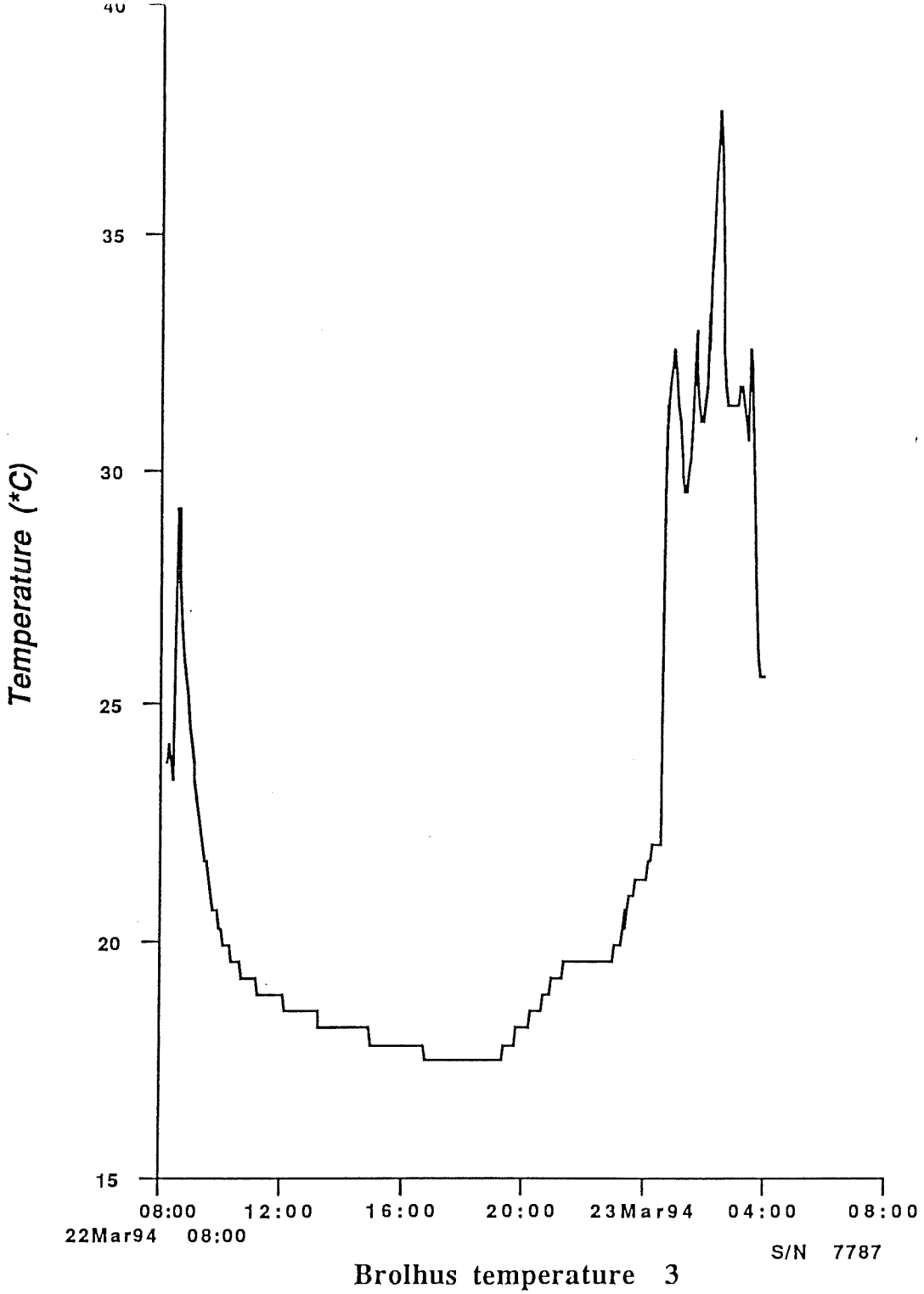

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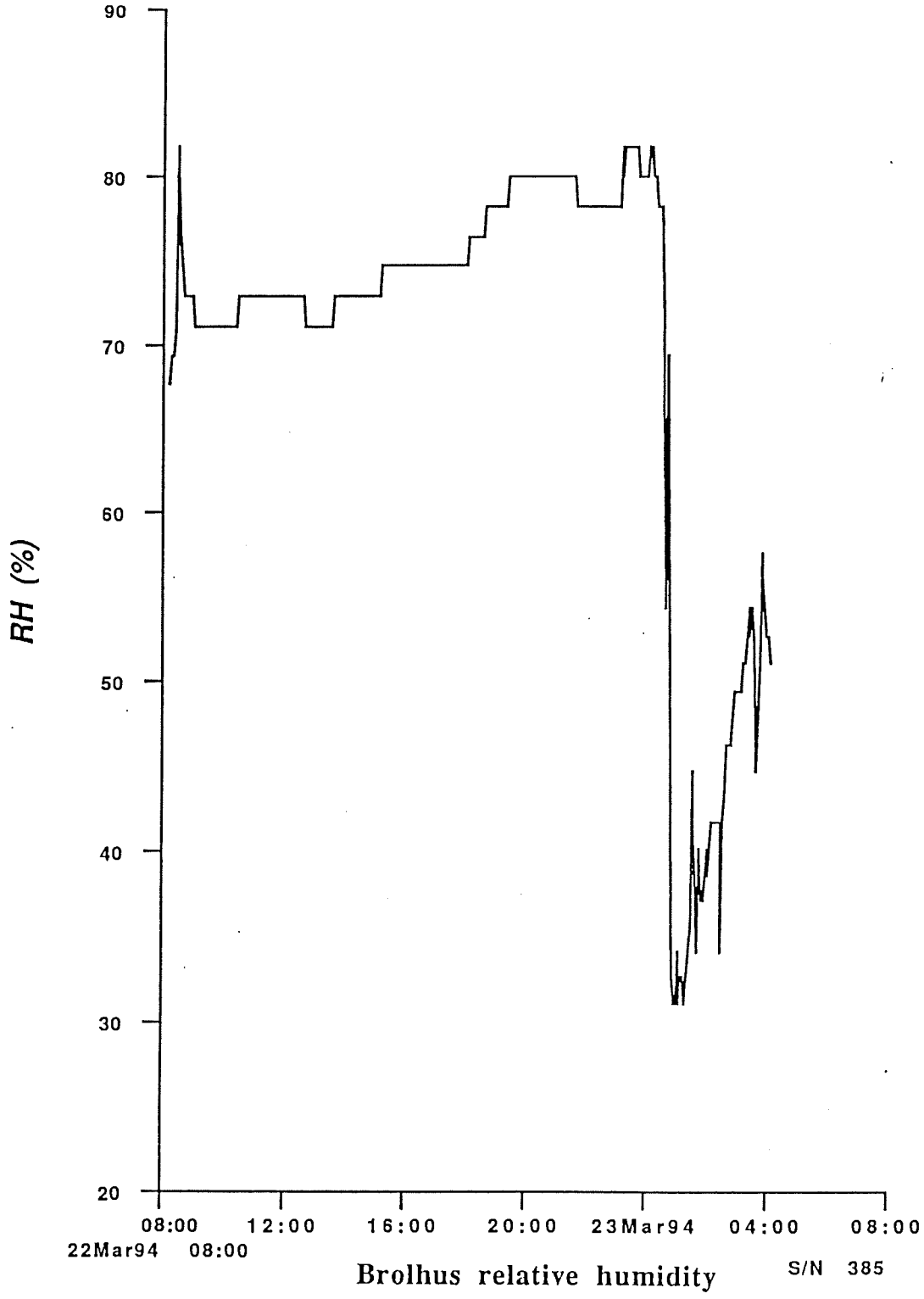

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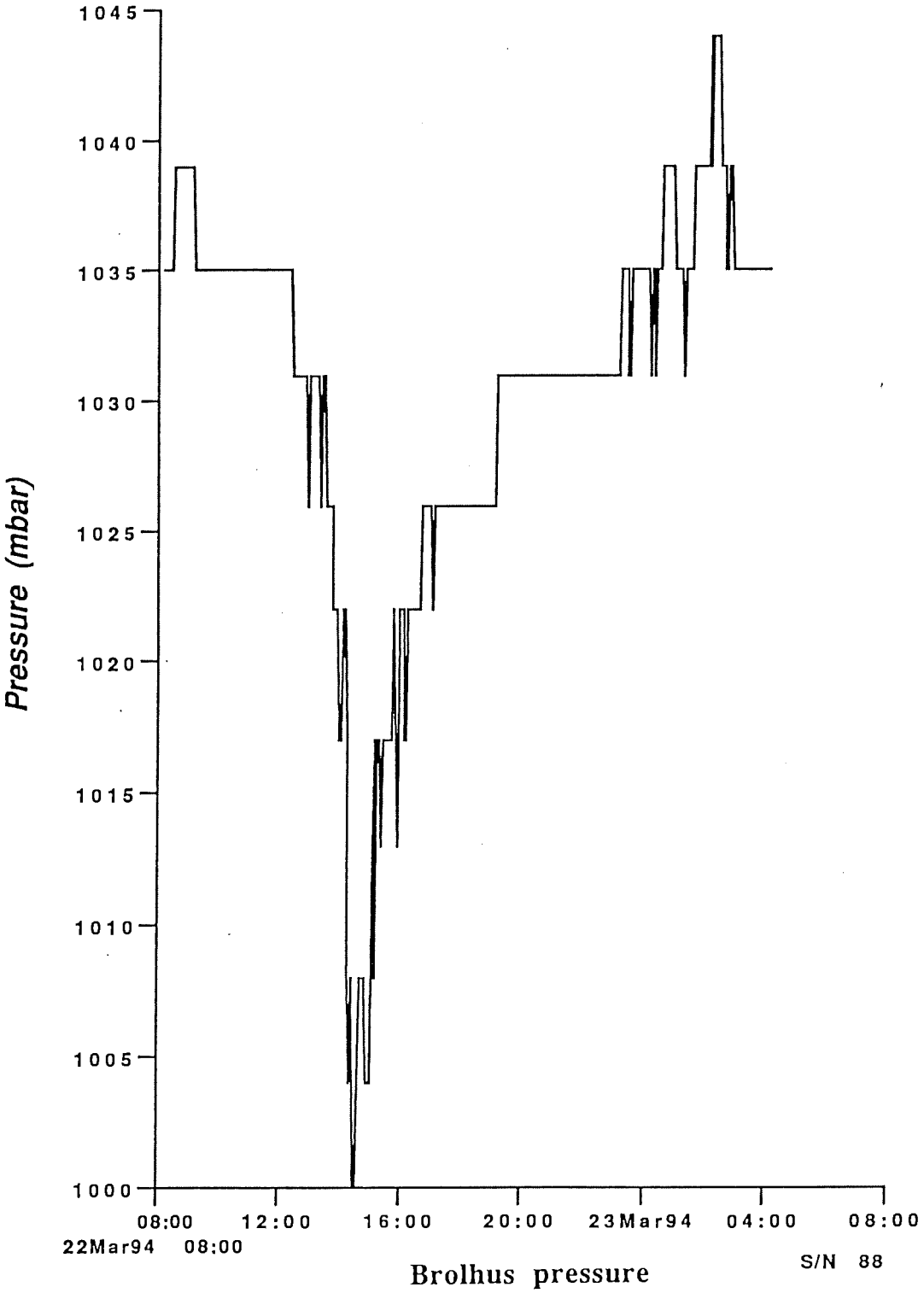

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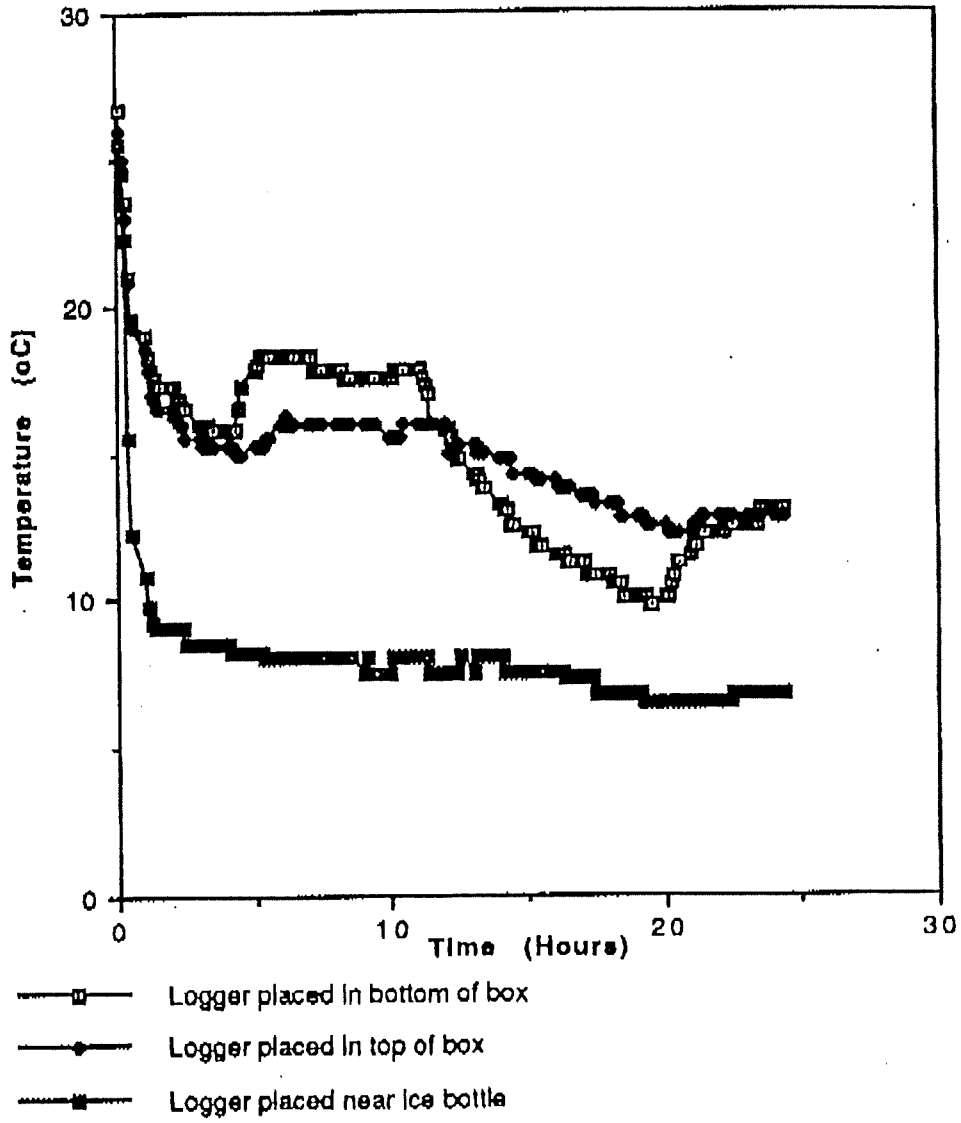
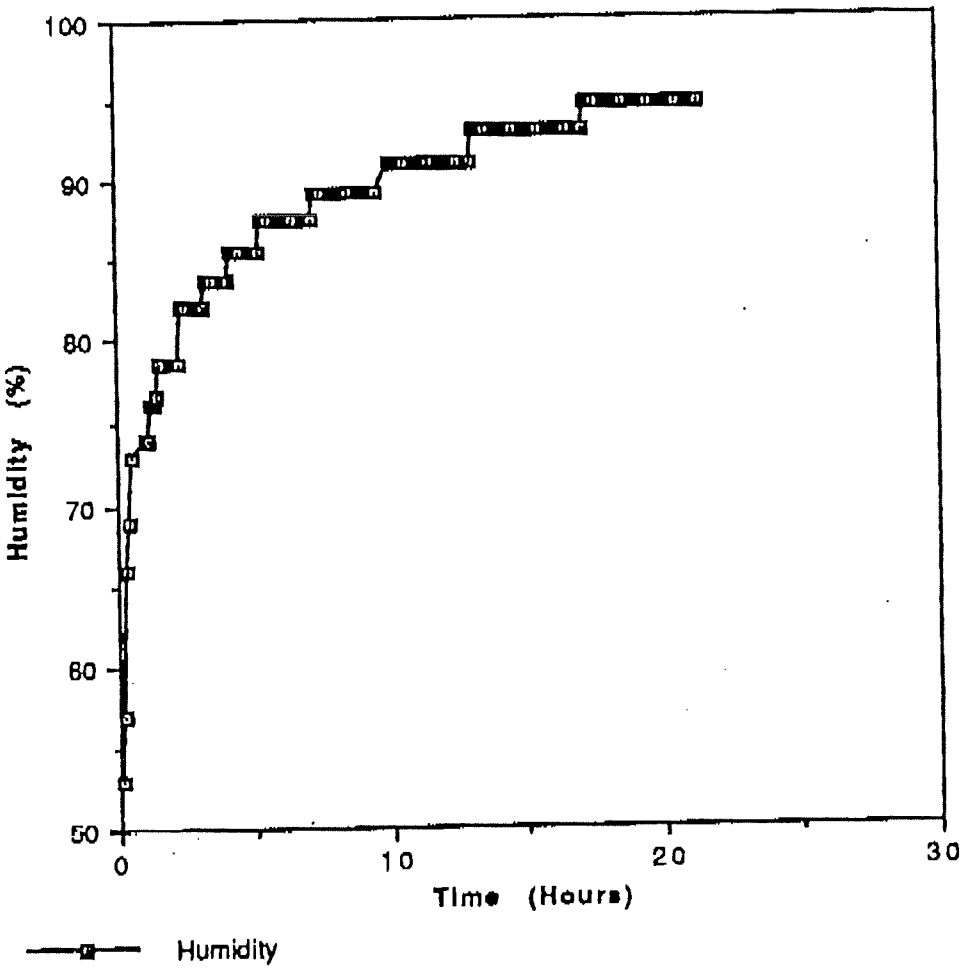
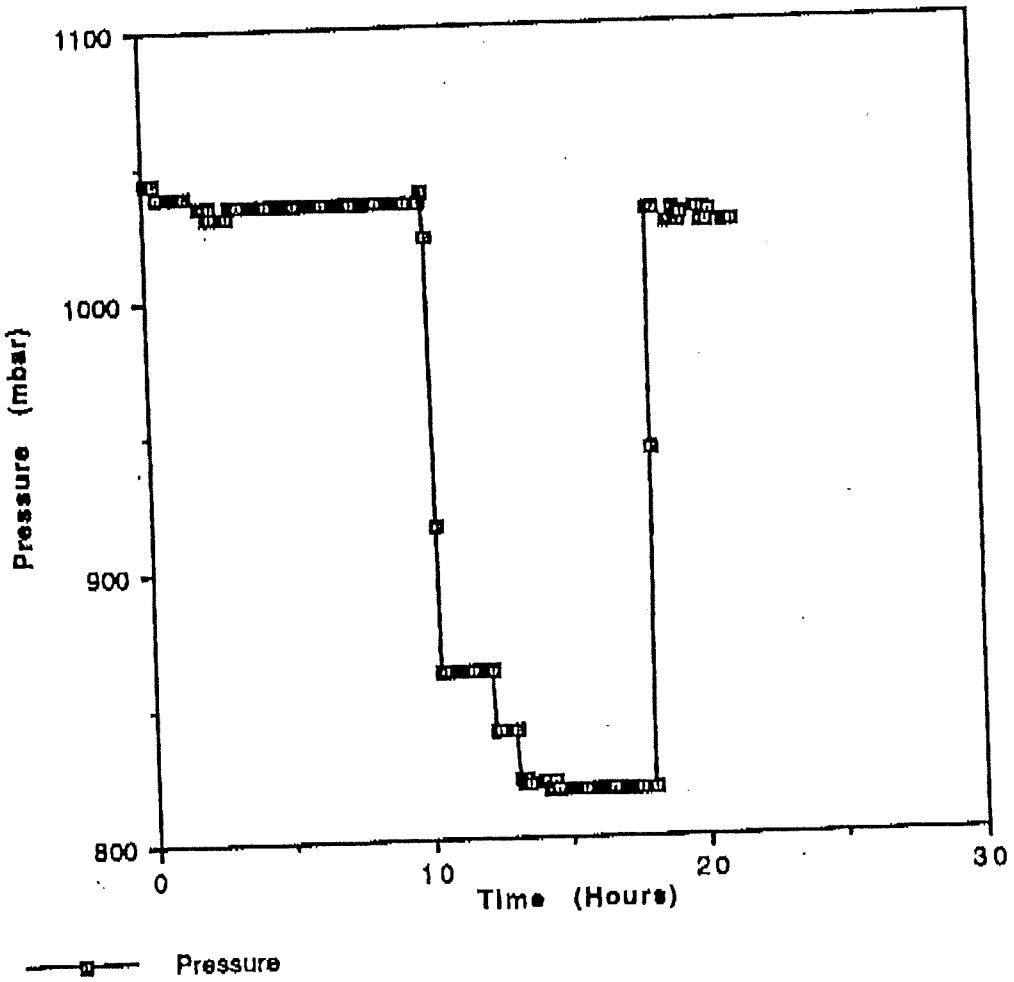
Temperature recordings in lobster box.
Lancelin to Tokyo 10th April 1994



Relative humidity recorded in lobster box. Lancelin to Tokyo 10th April 1994.



Pressure recorded in lobster box.
Lancelin to Tokyo, 10th April 1994



活ロブスター到着時調査データ

ブランド：

到着日：H6-4-8

作業時間：PM12:45

ケースNO.	出荷リスト 尾数	出荷リスト 重量 (KG)	温度 箱内 (℃)	温度 箱冷 (℃)	塩分濃度 (%)	実質重量 (KG)	死亡 尾数	死亡 重量 (KG)	足折れ 尾数	足折れ 本数	ヒゲ折れ	フン付	ウィーク	腹抜け
VO 07360	21尾	9.0K	15℃	B		8.78			T		T		T	
10 07369	22尾	9.0K	16℃	B		8.98			T		—		—	
10 07362	23尾	9.0K	13℃	B		9.08			T		—		—	
	22尾	9.0K	13℃	B		9.02			T		T		—	
合計														
%														

41

	出荷リスト 尾数	出荷リスト 重量 (KG)	ケース数
サイズ			
A			
B			
合計			

ⓐ到着時死亡 尾数	ⓐ到着時死亡 重量 (KG)	ⓑ翌朝死亡 尾数	ⓑ翌朝死亡 重量 (KG)
4尾	1.64		
死亡率			

水温：16℃

塩分濃度：3.4%

P.H.：0.15mg

アンモニア：0.25mg.

溶存酸素：

<コメント>

- 海色（水槽の色(良)）
- 海老の色は、コーラル系が1箱に2本平均
- 海老の状態は、入荷時、特に問題ない
- 尾数が、多いほど全箱重量が9.0Kgオーバーしている

水質 室内

活ロブスター到着時調査データ

到着日：H6. 63. 24

作業時間：12：30

ブランド：

ケースNO.	出荷リスト 尾数	出荷リスト 重量 (KG)	温度 箱内 (℃)	温度 蓄冷 (℃)	塩分濃度 (‰)	実質重量 (KG)	死亡 尾数	死亡 重量 (KG)	足折れ 尾数	足折れ 本数	ヒゲ折れ	フン付	ウィーク	最抜け
	17	8.0	15	10	3.6	7.26		0.82	T		T			
	19	8.0	15	9		8.01		0.42	—		—			
	19	8.0	16	13		7.74		0.80	T		—		下	
	18	8.0	14	12		7.64		0.38	—		—			
	17	8.0	15	14		7.18		0.84	T		下		—	
	18	8.0	15	13		7.76		0.42	—		—		上	
	18	8.0	17	10		7.46					T		—	
合計														
%														

42

	出荷リスト 尾数	出荷リスト 重量 (KG)	ケース数
サイズ			
A			
B			
合計			

Ⓐ到着時死亡 尾数	Ⓐ到着時死亡 重量 (KG)	Ⓑ翌朝死亡 尾数	Ⓑ翌朝死亡 重量 (KG)
28P	11.92	63P	27.2
17P	2.01		
9P	4.0		
24P	10.1		
	33.02		60.22
	死亡率		12.54%

水温：17℃

塩分濃度：3.7

P.H.：✓

アンモニア：✓

溶存酸素：(大)

<コメント>

9メ切れ多し

9到着死亡多し

0翌日死亡多し

9ビクラス

●死亡率 12.54%は最近ではめずらしい。

照井

5. EXPERIMENTS TO MEASURE THE IMPACTS OF VARIOUS FACTORS ON TEMPERATURES WITHIN ESKIS USING CANNED PRODUCT TO SIMULATE LOBSTERS

5.1 INTRODUCTION

One of the biggest problems encountered in research with rock lobsters is the cost of the lobster. This limits the amount of experimentation that can be economically carried out with a consequential risk of leaving many unanswered questions.

From discussions with rock lobster processors there were a number of basic questions about temperature conditions within the eskis for which we required answers. The simplest and cheapest way to obtain relative information on changing conditions during transport was to simulate live shipments using eskis full of cans instead of lobsters with a number of temperature probes located at various positions in the eski. Eight separate trials were carried out and are detailed below followed by summary and conclusions.

5.2 MATERIALS AND METHODS

Standard "10kg" polystyrene foam eskis, water bottles and wood shavings were obtained from a rock lobster processor.

Dry-Chill packaging prefilled bubble wrapped units from Dry Chill Pty Ltd, Warragal, Vic, 3820.

Insul-box; foil coated cardboard eski and foil coated ice pack from Insul-box, Gold Coast, Queensland, 4219.

74mm x 112mm cans of tomatoes with gross weight = 450g

A Eurotherm 12 channel temperature recorder was fitted with T-type thermocouple wire with a soldered junction. All probes were connected and checked in melting ice to confirm temperatures within +/- 0.5°C.

Except where indicated in the particular trial methodology five probes were used to measure temperatures within the 'trial' and 'control' eskis plus an additional probe recording ambient air temperature.

Three internal probes were located attached to cans close to the centre of the eski; one at the bottom; one at the top and one in the middle. The two additional probes were located in corners of the eski, one at the top and one at the bottom diagonally opposite.

The eskis were packed using a layer of wood shavings, layer of cans, cover in wood shavings, layer of cans, etc. 20 cans were packed equivalent to 9kg lobsters. Except where indicated in the trial method the ice bottles were wrapped in paper and packed close to the arithmetic centre of the eski.

The thermocouple wires were passed out of the open top and the lid secured over them with sellotape. Temperature recordings were made at various times throughout the trial with the eskis moved from room to room to provide the necessary temperature variation.

As the atmospheric conditions would vary trial to trial and because the trials were simulations, wherever practical the method used was to compare a trial eski against a standard and obtain relative differences.

The temperature readings over time for each experiment were tabulated and graphs drawn of the average temperatures as well as individual temperature probe readings over time.

5.3 EXPERIMENTATION

5.3.1 EXPERIMENT 1. TO MEASURE THE EFFECT OF AIR HOLES ON THE INTERNAL TEMPERATURE WHEN COMPARED WITH AN INTACT ESKI

Reason:- As a general rule air holes are punched out of the ends of eskis prior to packing. Since the function of the eski is to protect the contents from external temperature changes what impact does the air hole have on this function?

Method:- One eski had two holes punched out at each end near the base, each hole 12-15mm diameter. The other eski was left intact. Both eskis were packed with cans and wood shavings, stored under the same conditions and each eski kept cool using 2 x 500g frozen ice bottles wrapped in paper.

Results:- Probes 1-5 were in the control eski, probes 6-10 in the eski with air holes. The average temperature from all the probe readings of the control eski was 10.2°C, whilst that of the trial was 11.8°C. This compared with the average air temperature of 19.8°C.

Whilst this suggests the air holes do make a difference, it is clear from the results that any difference is small when compared with the temperature differences within the eskis.

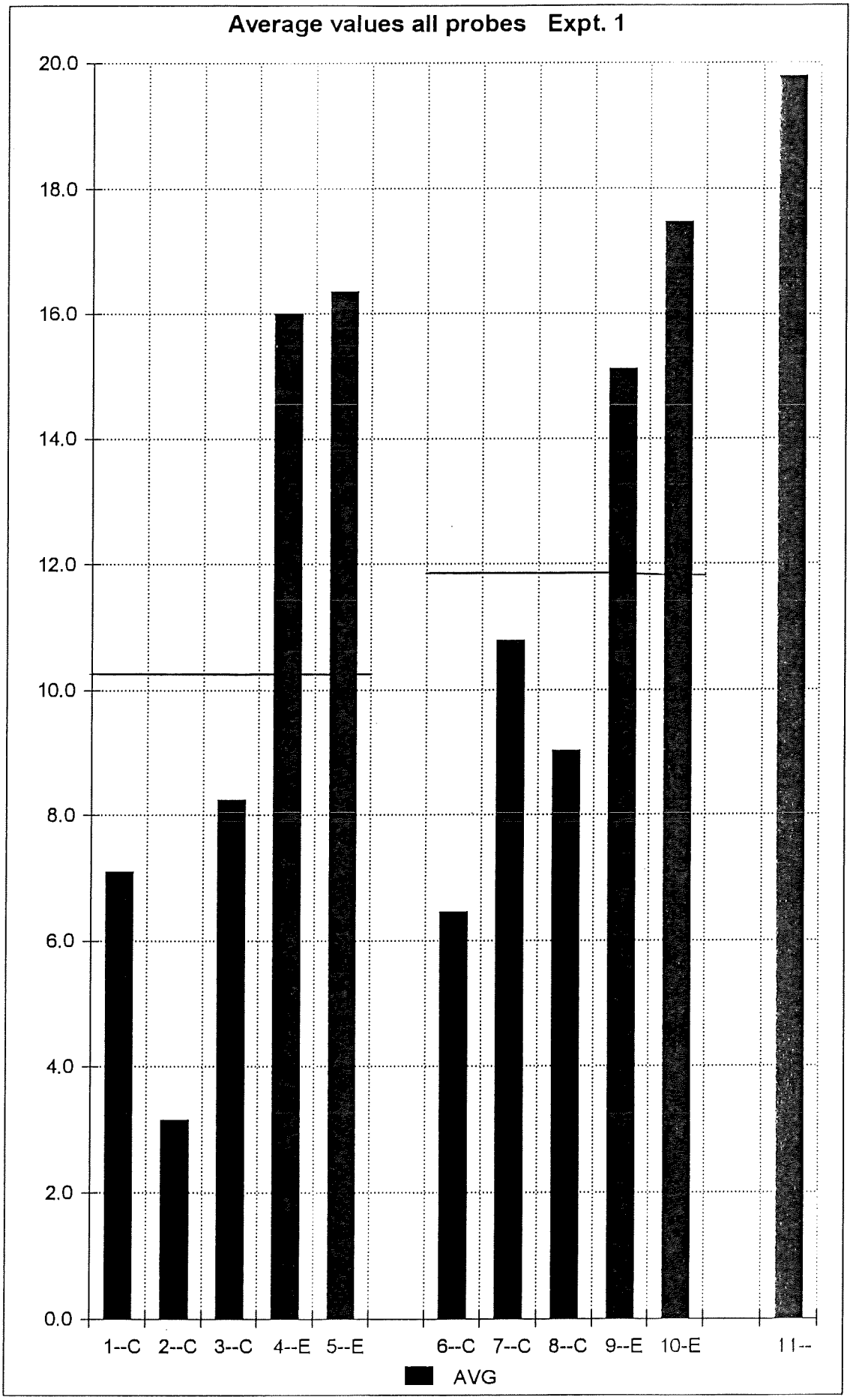
This is most strikingly seen from the all data plots which show the temperatures near the corners of the eskis (Probes 4,5; 9,10) a few degrees below the air temperature, but fluctuating in unison with the air, whilst the centre temperatures are considerably lower and protected by position and/or the influence of the ice pack.

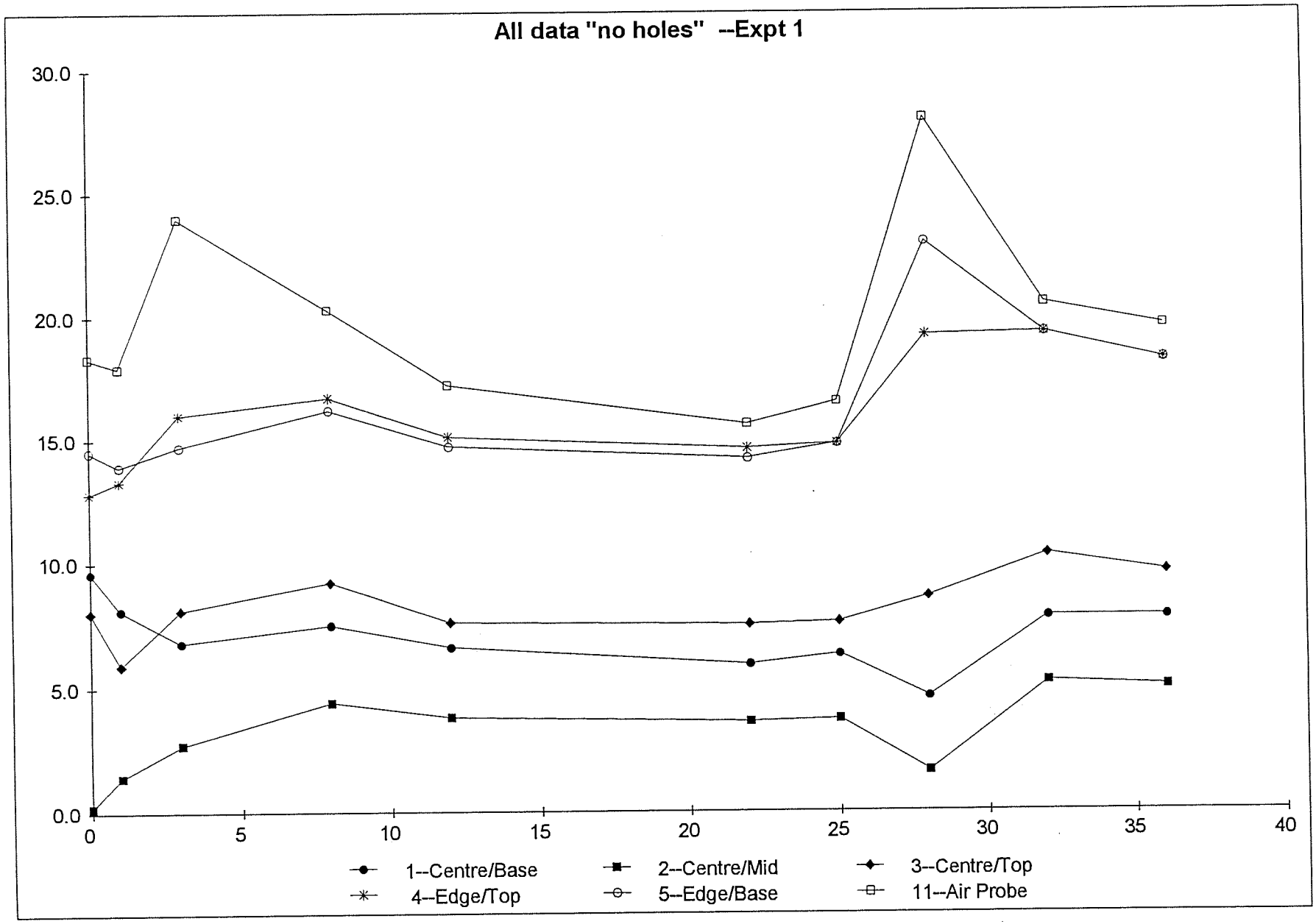
As expected, when the external temperature was at it's highest the air hole eski had the highest edge temperatures. This could be relevant if there is a defined maximum temperature for survival of lobsters during transport.

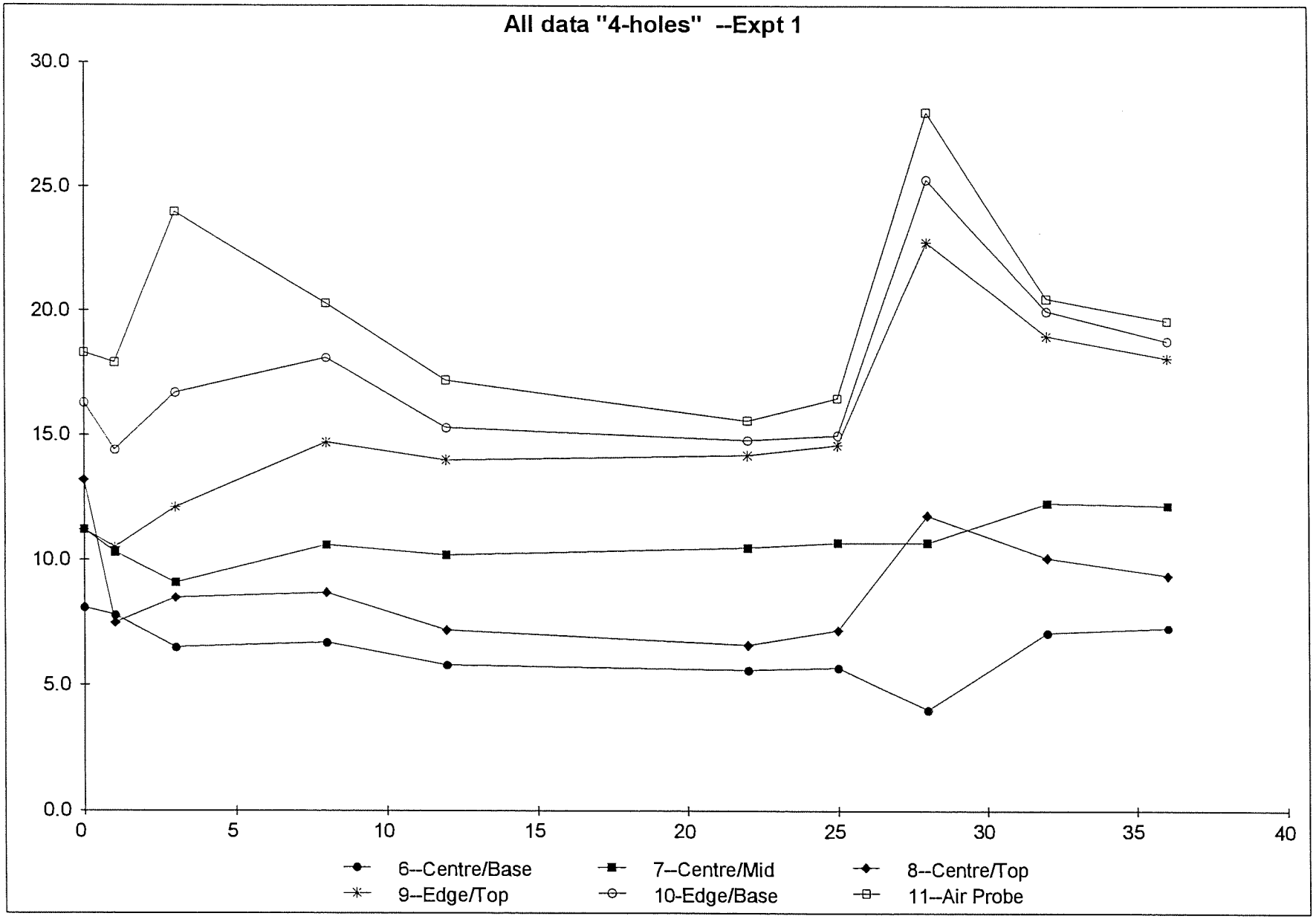
Experiment 1-Effect of 4 air holes on temperature within eskis

Probe Temps **Time- Hours**

	0	1	3	8	12	22	25	28	32	36	AVG
1--Centre/Base	9.6	8.1	6.8	7.5	6.6	5.9	6.3	4.6	7.8	7.8	**7.1**
2--Centre/Mid	0.2	1.4	2.7	4.4	3.8	3.6	3.7	1.6	5.2	5.0	**3.2**
3--Centre/Top	8.0	5.9	8.1	9.2	7.6	7.5	7.6	8.6	10.3	9.6	**8.2**
4--Edge/Top	12.8	13.3	16.0	16.7	15.1	14.6	14.8	19.2	19.3	18.2	**16.0**
5--Edge/Base	14.5	13.9	14.7	16.2	14.7	14.2	14.8	23.0	19.3	18.2	**16.4**
6--Centre/Base	8.1	7.8	6.5	6.7	5.8	5.6	5.7	4.0	7.1	7.3	**6.5**
7--Centre/Mid	11.2	10.3	9.1	10.6	10.2	10.5	10.7	10.7	12.3	12.2	**10.8**
8--Centre/Top	13.2	7.5	8.5	8.7	7.2	6.6	7.2	11.8	10.1	9.4	**9.0**
9--Edge/Top	11.2	10.5	12.1	14.7	14.0	14.2	14.6	22.8	19.0	18.1	**15.1**
10-Edge/Base	16.3	14.4	16.7	18.1	15.3	14.8	15.0	25.3	20.0	18.8	**17.5**
11--Air Probe	18.3	17.9	24.0	20.3	17.2	15.6	16.5	28.0	20.5	19.6	**19.8**


Average values all probes Expt. 1
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1--C
2--C
3--C
4--E
5--E
6--C
7--C
8--C
9--E
10-E
11--
AVG


All data "no holes" --Expt 1
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0
5
10
15
20
25
30
35
40
1--Centre/Base
2--Centre/Mid
3--Centre/Top
4--Edge/Top
5--Edge/Base
11--Air Probe


All data "4-holes" --Expt 1
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0
5
10
15
20
25
30
35
40
6--Centre/Base
7--Centre/Mid
8--Centre/Top
9--Edge/Top
10-Edge/Base
11--Air Probe

5.3.2 EXPERIMENT 2. TO MEASURE THE EFFECT OF PRE-CHILLING WOOD SHAVINGS ON THE TEMPERATURE WITHIN THE ESKI

Reason:- In the middle of summer stored shavings will be at temperatures in excess of 20°C. As the live export packaging system is designed to keep lobsters cool do warm wood shavings negatively impact on this?

Method:- An eski of wood shavings was kept in the freezer overnight and then used to pack around cans in an eski without air holes. A similar eski was packed with room temperature shavings as a control. A 1kg ice pack was included in each eski.

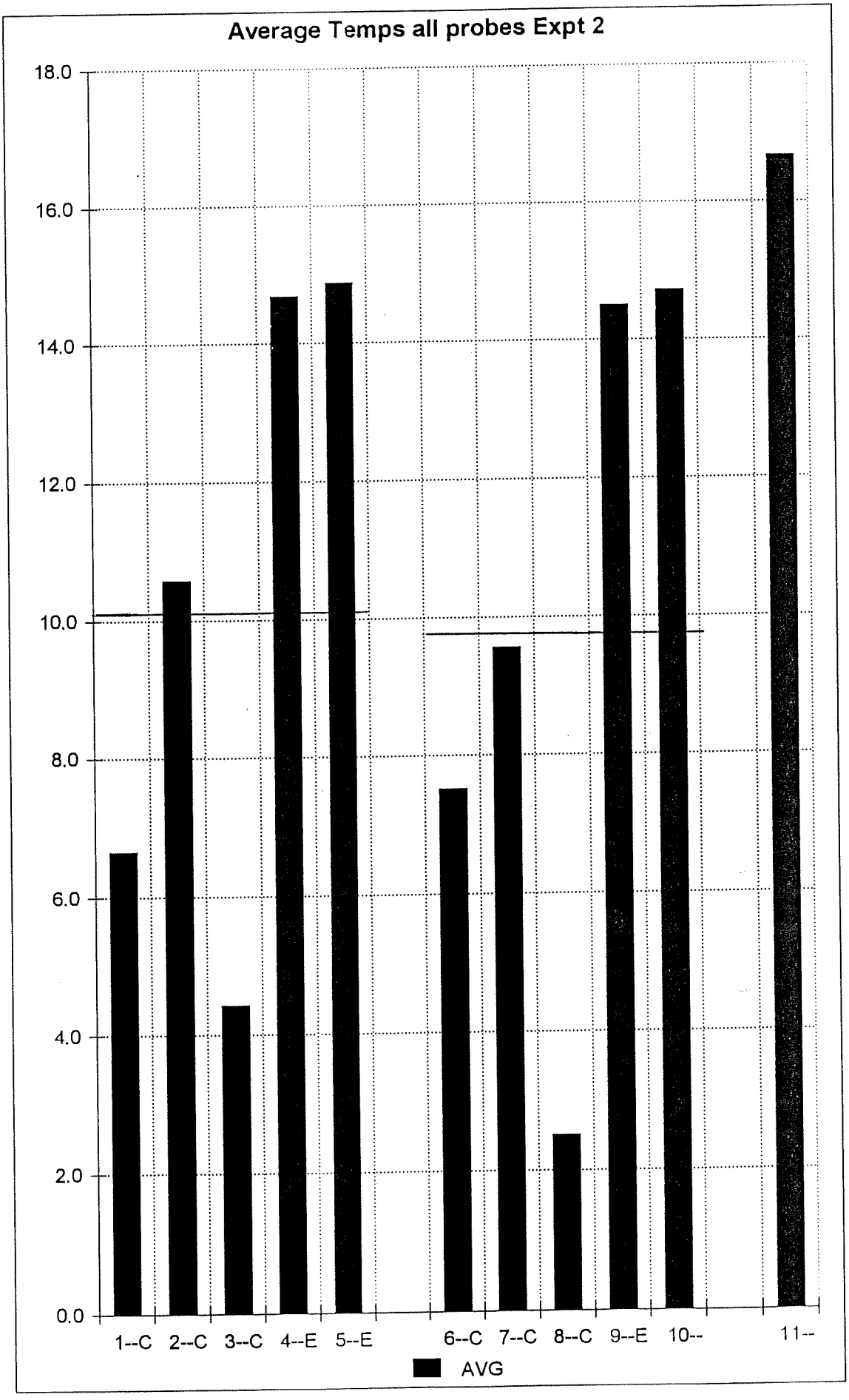
Results:- The initial temperature of the eski with the chilled shavings was lower than the control, but after only one hour the temperature difference was reduced and whilst the average temperature over the whole experiment was 1.5°C lower with the chilled shavings, this was small compared with other variations within the eski.

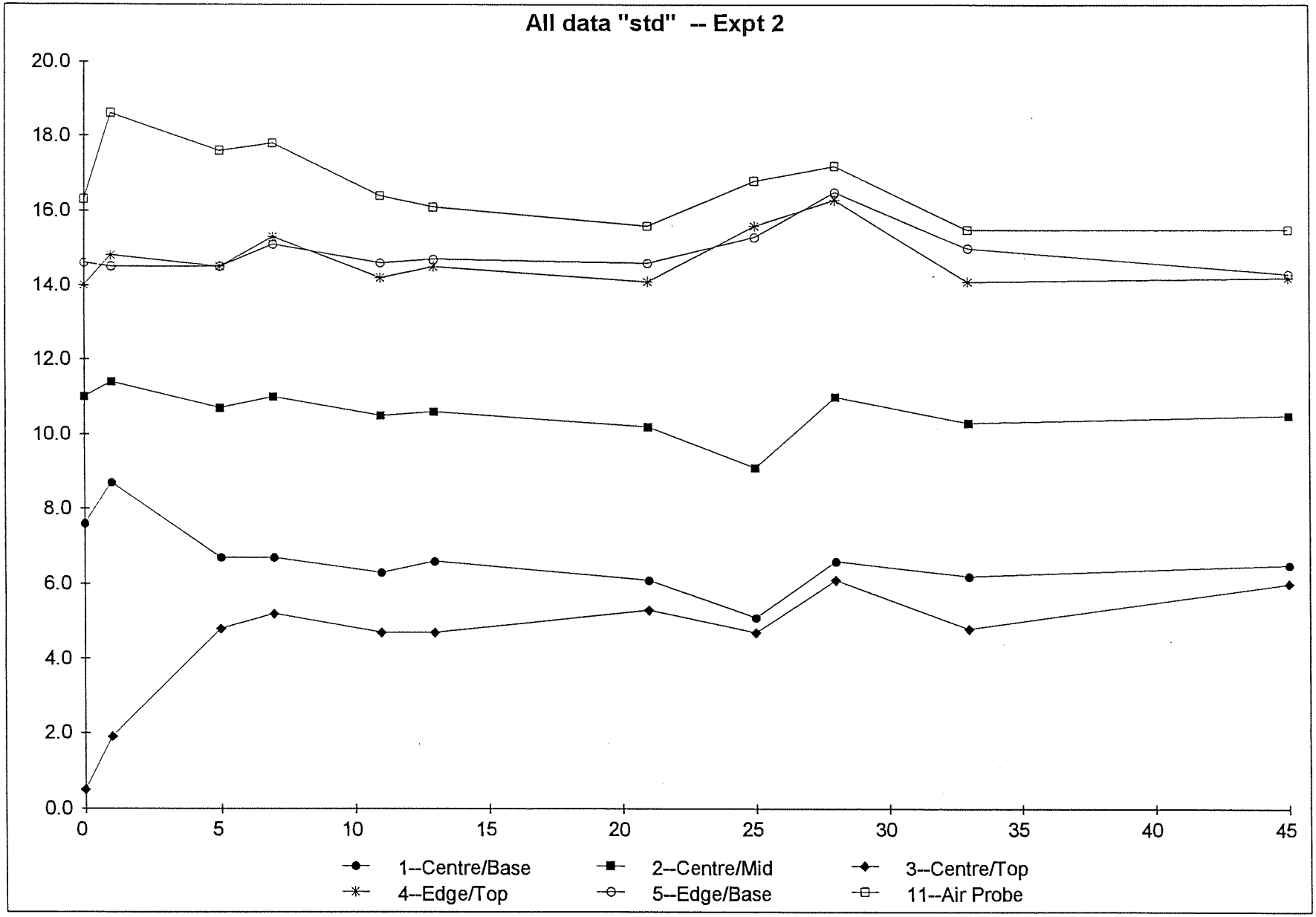
The weight and thermal capacity of the wood shavings is thus too small to impact markedly on temperature. The results, however, confirm the pattern of temperature distribution within the eskis noted in Experiment 1.

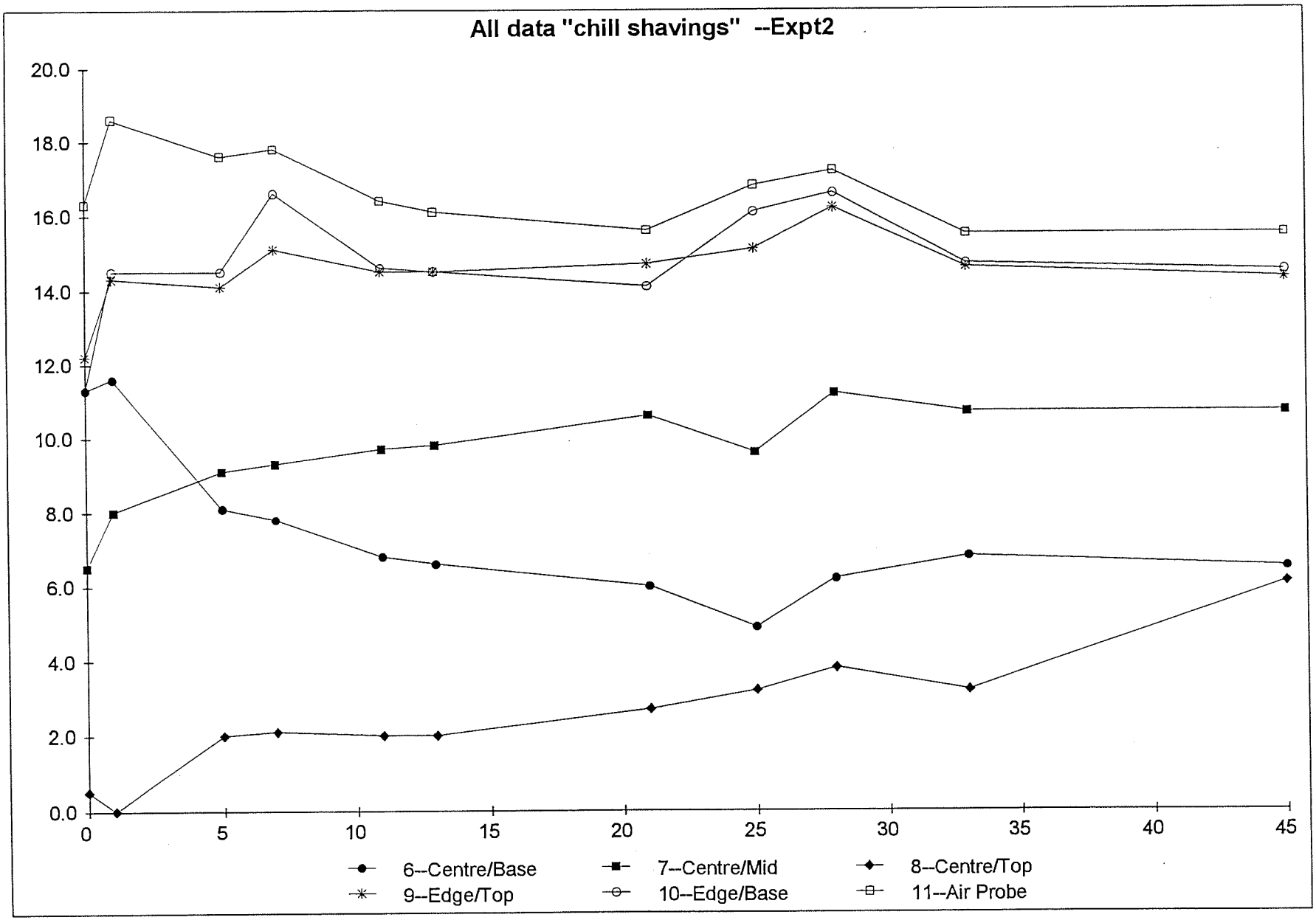
Experiment 2 - Effect of pre-chilled wood shavings on temperatures within eskis

Probe Temps **Time - Hours**

	0	1	5	7	11	13	21	25	28	33	45	AVG
1--Centre/Base	7.6	8.7	6.7	6.7	6.3	6.6	6.1	5.1	6.6	6.2	6.5	**6.6**
2--Centre/Mid	11.0	11.4	10.7	11.0	10.5	10.6	10.2	9.1	11.0	10.3	10.5	**10.6**
3--Centre/Top	0.5	1.9	4.8	5.2	4.7	4.7	5.3	4.7	6.1	4.8	6.0	**4.4**
4--Edge/Top	14.0	14.8	14.5	15.3	14.2	14.5	14.1	15.6	16.3	14.1	14.2	**14.7**
5--Edge/Base	14.6	14.5	14.5	15.1	14.6	14.7	14.6	15.3	16.5	15.0	14.3	**14.9**
6--Centre/Base	11.3	11.6	8.1	7.8	6.8	6.6	6.0	4.9	6.2	6.8	6.5	**7.5**
7--Centre/Mid	6.5	8.0	9.1	9.3	9.7	9.8	10.6	9.6	11.2	10.7	10.7	**9.6**
8--Centre/Top	0.5	0.0	2.0	2.1	2.0	2.0	2.7	3.2	3.8	3.2	6.1	**2.5**
9--Edge/Top	12.2	14.3	14.1	15.1	14.5	14.5	14.7	15.1	16.2	14.6	14.3	**14.5**
10--Edge/Base	11.3	14.5	14.5	16.6	14.6	14.5	14.1	16.1	16.6	14.7	14.5	**14.7**
11--Air Probe	16.3	18.6	17.6	17.8	16.4	16.1	15.6	16.8	17.2	15.5	15.5	**16.7**


Average Temps all probes Expt 2
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1--C
2--C
3--C
4--E
5--E
6--C
7--C
8--C
9--E
10--
11--
AVG


All data "std" -- Expt 2
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
5
10
15
20
25
30
35
40
45
1--Centre/Base
2--Centre/Mid
3--Centre/Top
4--Edge/Top
5--Edge/Base
11--Air Probe


All data "chill shavings" --Expt2
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
5
10
15
20
25
30
35
40
45
6--Centre/Base
7--Centre/Mid
8--Centre/Top
9--Edge/Top
10--Edge/Base
11--Air Probe

5.3.3 EXPERIMENT 3. TO MEASURE THE EFFECT OF DIFFERENT "LOBSTER" TEMPERATURES ON TEMPERATURE CONTROL WITHIN THE ESKI

Reason:- Discussions with processors had revealed that all reduce the temperatures of the lobsters prior to packing. However, whilst some maintain the lobsters for a period of time in chilled water, others shock chill with a short time dip. What is the impact of pre-chilling on the temperature control in an eski?

Method:- One batch of cans was chilled to 8°C, whilst the controls were maintained at ambient of 15°C. Both eskis were packed without air holes using ambient wood shavings and a 1kg ice pack.

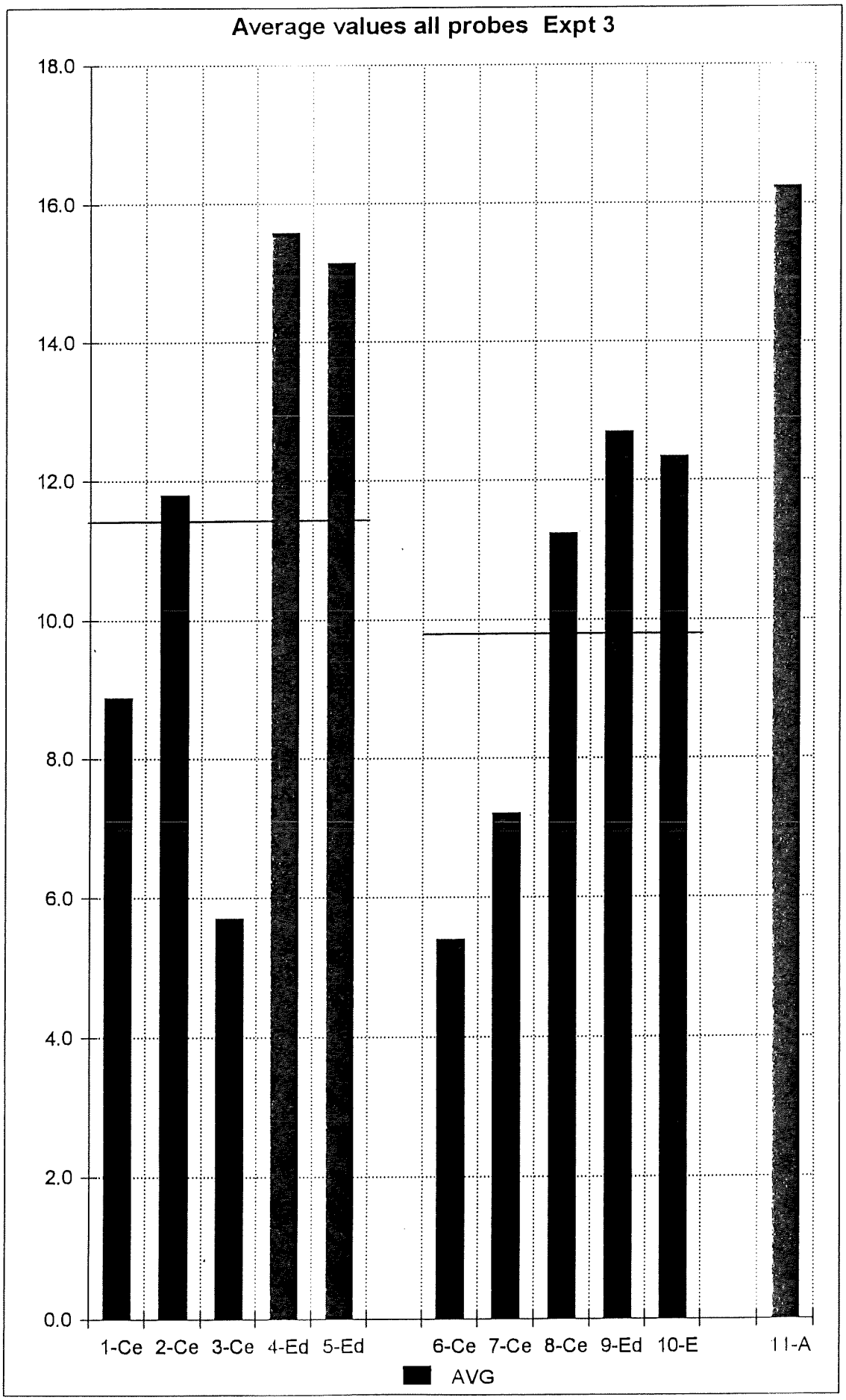
Results:- The average temperature of the eski with chilled lobsters was 1.6°C lower than the control over 40 hours. That temperature difference is obvious in the early part of the experiment, with a greater than 2°C difference up to 14 hours. At the end of the experiment there remained 500g of ice in the trial eski and only 300g in the control.

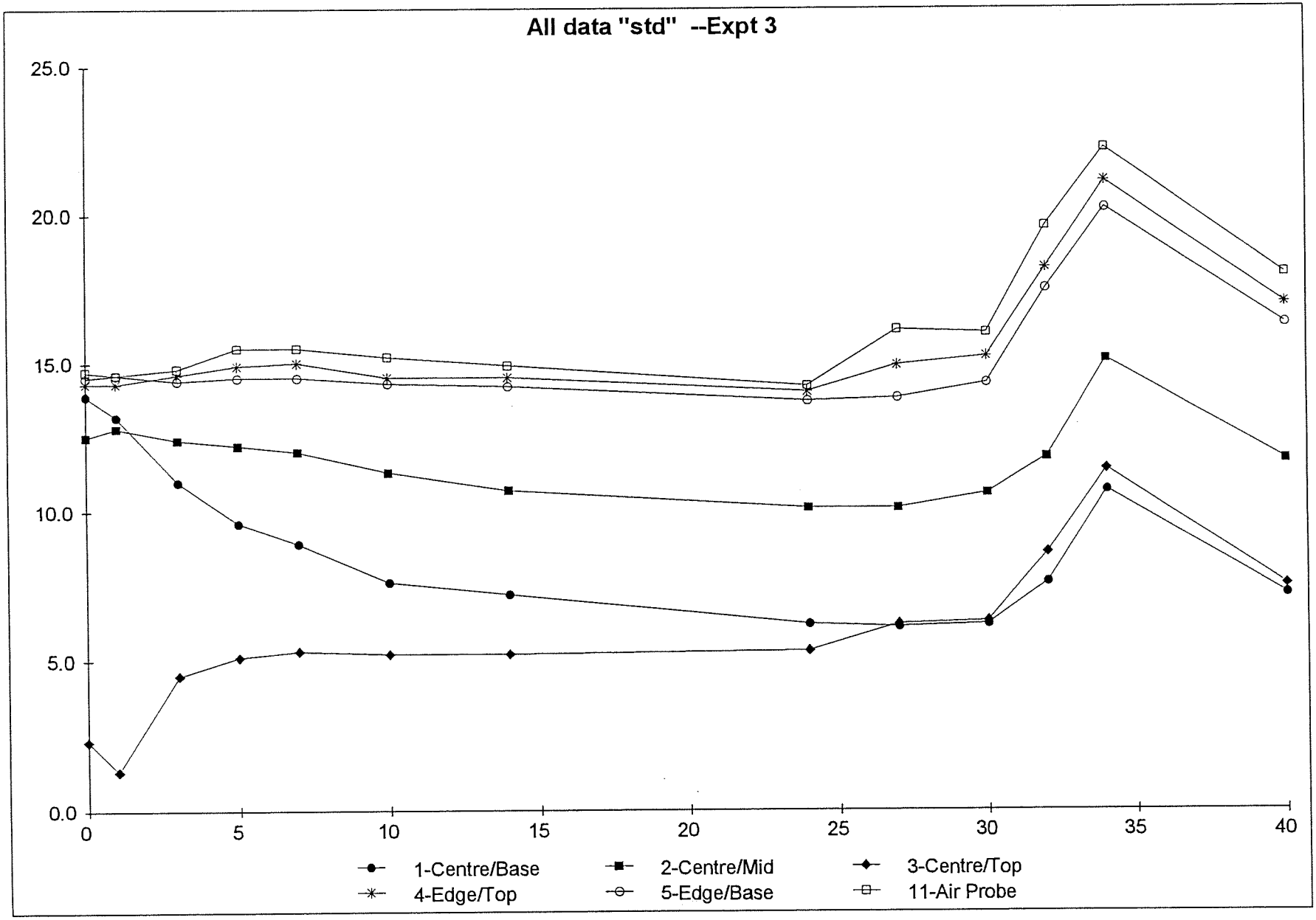
The pattern of the control/standard eski temperatures was, again, very similar to the earlier trials with the probes near the edge showing temperatures slightly below ambient, whilst those in the middle, particularly close to the ice pack, being much lower. The trial eski showed a different pattern where the pre-chilling helped maintain a much larger differential of the 'edge' readings compared with ambient in the first 24 hours.

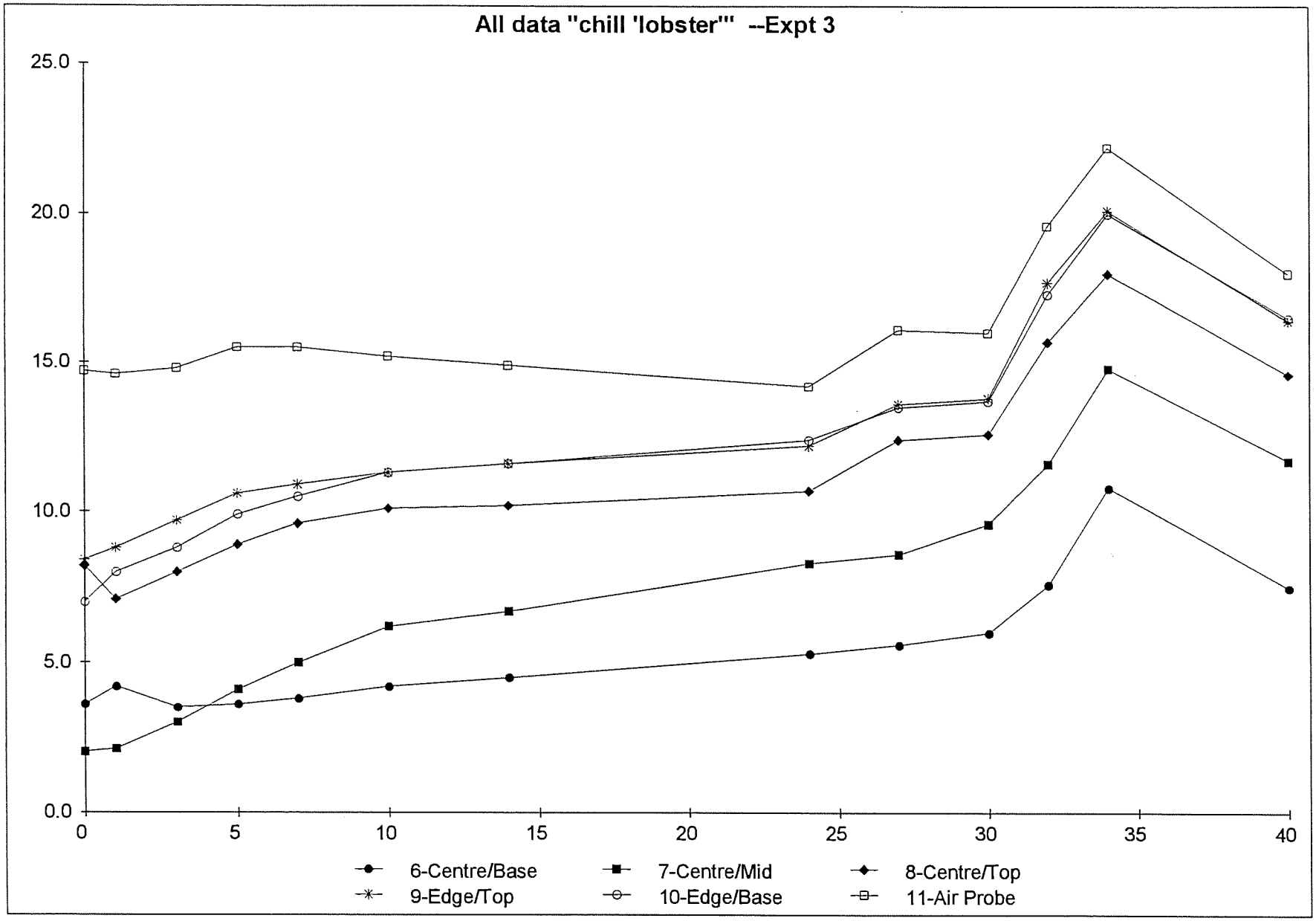
Experiment 3 - Effect of "lobster" temp. on temps. within eskis

Probe Temps **Time - Hours**

	0	1	3	5	7	10	14	24	27	30	32	34	40	AVG
1-Centre/Base	13.9	13.2	11.0	9.6	8.9	7.6	7.2	6.2	6.1	6.2	7.6	10.7	7.2	**8.9**
2-Centre/Mid	12.5	12.8	12.4	12.2	12.0	11.3	10.7	10.1	10.1	10.6	11.8	15.1	11.7	**11.8**
3-Centre/Top	2.3	1.3	4.5	5.1	5.3	5.2	5.2	5.3	6.2	6.3	8.6	11.4	7.5	**5.7**
4-Edge/Top	14.3	14.3	14.6	14.9	15.0	14.5	14.5	14.0	14.9	15.2	18.2	21.1	17.0	**15.6**
5-Edge/Base	14.5	14.6	14.4	14.5	14.5	14.3	14.2	13.7	13.8	14.3	17.5	20.2	16.3	**15.1**
6-Centre/Base	3.6	4.2	3.5	3.6	3.8	4.2	4.5	5.3	5.6	6.0	7.6	10.8	7.5	**5.4**
7-Centre/Mid	2.0	2.1	3.0	4.1	5.0	6.2	6.7	8.3	8.6	9.6	11.6	14.8	11.7	**7.2**
8-Centre/Top	8.2	7.1	8.0	8.9	9.6	10.1	10.2	10.7	12.4	12.6	15.7	18.0	14.6	**11.2**
9-Edge/Top	8.4	8.8	9.7	10.6	10.9	11.3	11.6	12.2	13.6	13.8	17.7	20.1	16.4	**12.7**
10-Edge/Base	7.0	8.0	8.8	9.9	10.5	11.3	11.6	12.4	13.5	13.7	17.3	20.0	16.5	**12.3**
11-Air Probe	14.7	14.6	14.8	15.5	15.5	15.2	14.9	14.2	16.1	16.0	19.6	22.2	18.0	**16.3**


Average values all probes Expt 3
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1-Ce
2-Ce
3-Ce
4-Ed
5-Ed
6-Ce
7-Ce
8-Ce
9-Ed
10-E
11-A
AVG


All data "std" --Expt 3
25.0
20.0
15.0
10.0
5.0
0.0
0
5
10
15
20
25
30
35
40
1-Centre/Base
2-Centre/Mid
3-Centre/Top
4-Edge/Top
5-Edge/Base
11-Air Probe


All data "chill 'lobster'" --Expt 3
25.0
20.0
15.0
10.0
5.0
0.0
0
5
10
15
20
25
30
35
40
6-Centre/Base
7-Centre/Mid
8-Centre/Top
9-Edge/Top
10-Edge/Base
11-Air Probe

5.3.4 EXPERIMENT 4. TO COMPARE THE EFFECTIVENESS OF DRY CHILL "ICE PACKS" AND ICE BOTTLES ON TEMPERATURE CONTROL WITHIN THE ESKI

Reason:- A number of pre-prepared ice packs are available, some of which contain chemicals to improve the cooling efficiency. Time did not allow a detailed study of the effectiveness of the various types available, but a simple comparison of one type was considered valid.

Method:- Two eskis were prepared from identically stored cans and packaging. To one was added a standard 1kg ice pack, whilst into the other was packed a 1kg pre-frozen "Dry Chill 2000" bubble. wrapped pack
The surface area of the dry chill pack was larger than that of the ice bottles.

Results:- The average temperature of the trial eski with the dry chill was 1°C lower than the standard over the duration of the trial. After 36 hours ice remained in the bottles and dry chill.

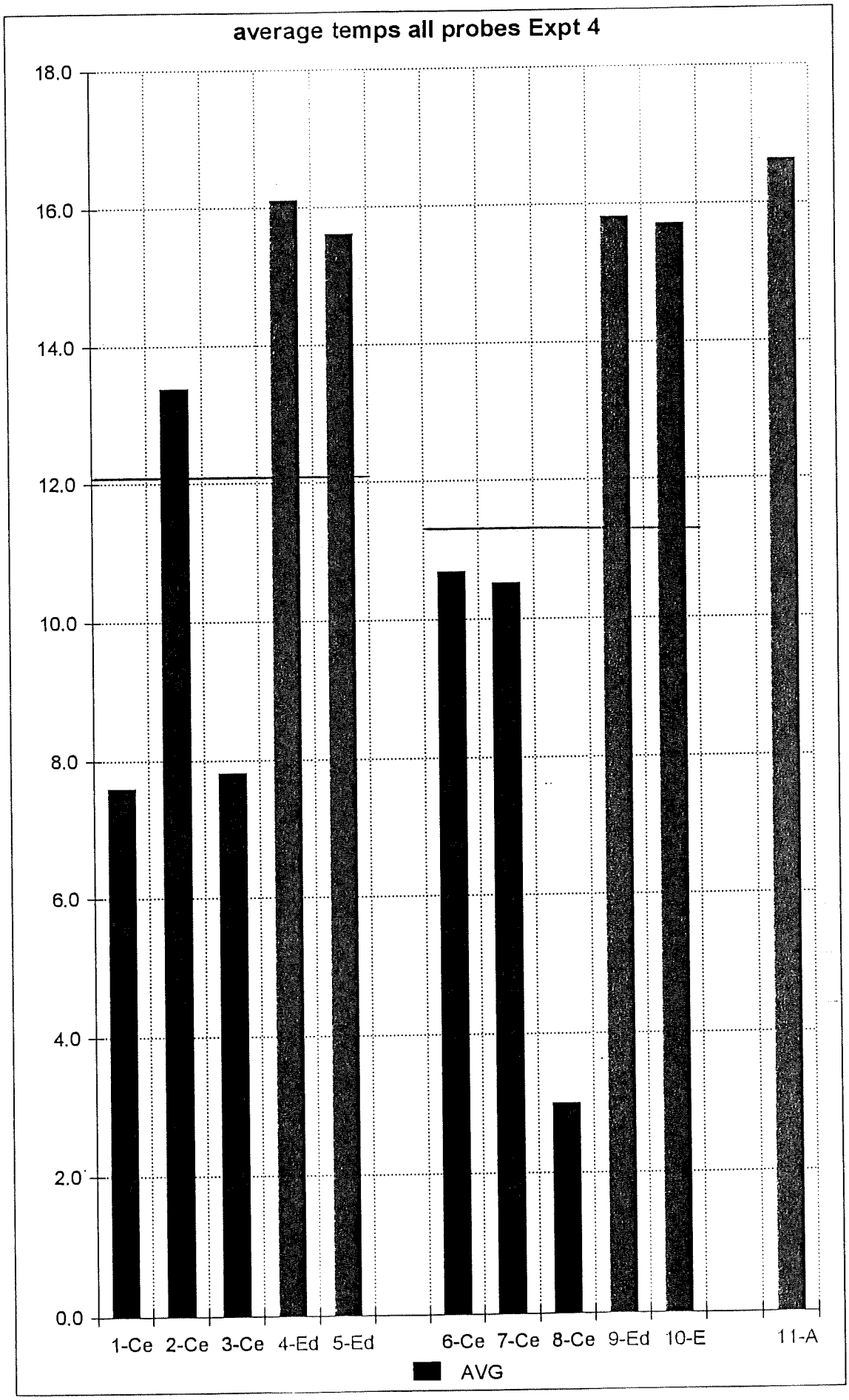
The patterns of temperature change within the eskis were similar, suggesting little difference in cooling effectiveness. The marked differences in readings between probes 3 and 8 probably reflects the precise position of the probe relative to the ice pack or dry chill pack rather than more or less cooling.

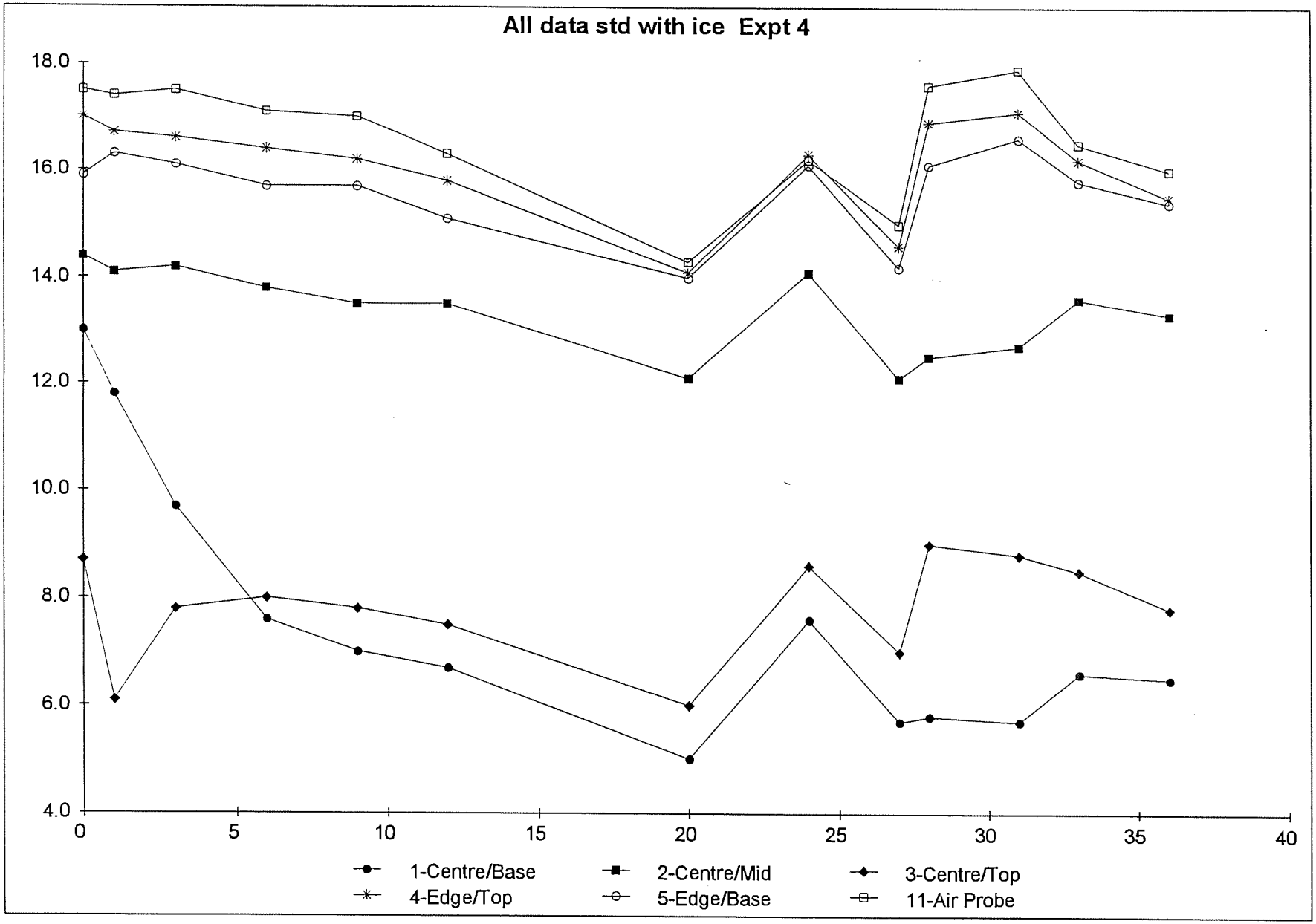
However, in the real situation what impact does an ice pack very close to a lobster have on the risk of mortality? Can the lobster be chilled too much?

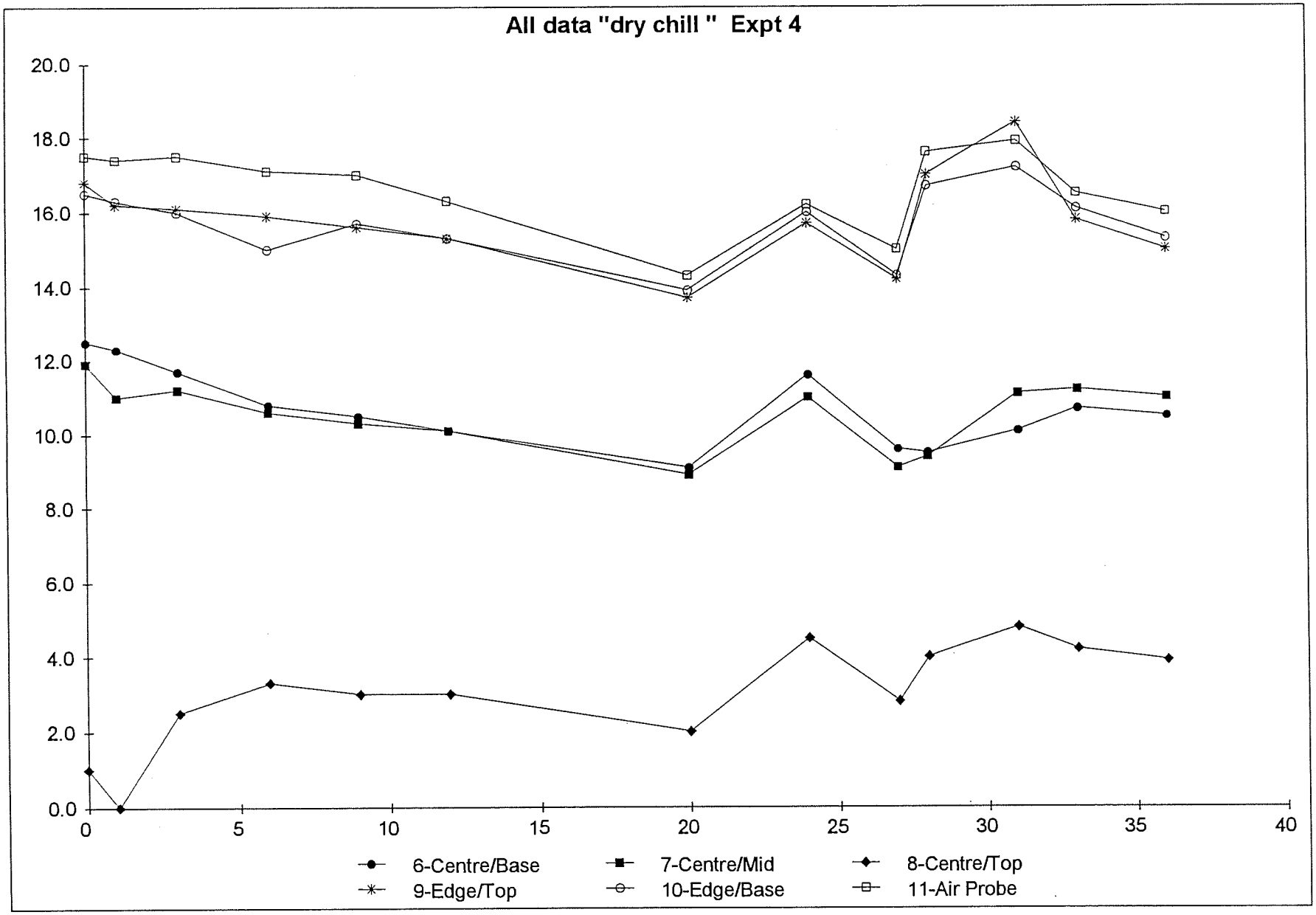
Experiment 4 - Effect of "Dry-Chill" packaging on temps within eskis

Probe Temps **Time - Hours**

	0	1	3	6	9	12	20	24	27	28	31	33	36	AVG
1-Centre/Base	13.0	11.8	9.7	7.6	7.0	6.7	5.0	7.6	5.7	5.8	5.7	6.6	6.5	**7.6**
2-Centre/Mid	14.4	14.1	14.2	13.8	13.5	13.5	12.1	14.1	12.1	12.5	12.7	13.6	13.3	**13.4**
3-Centre/Top	8.7	6.1	7.8	8.0	7.8	7.5	6.0	8.6	7.0	9.0	8.8	8.5	7.8	**7.8**
4-Edge/Top	17.0	16.7	16.6	16.4	16.2	15.8	14.1	16.3	14.6	16.9	17.1	16.2	15.5	**16.1**
5-Edge/Base	15.9	16.3	16.1	15.7	15.7	15.1	14.0	16.1	14.2	16.1	16.6	15.8	15.4	**15.6**
6-Centre/Base	12.5	12.3	11.7	10.8	10.5	10.1	9.1	11.6	9.6	9.5	10.1	10.7	10.5	**10.7**
7-Centre/Mid	11.9	11.0	11.2	10.6	10.3	10.1	8.9	11.0	9.1	9.4	11.1	11.2	11.0	**10.5**
8-Centre/Top	1.0	0.0	2.5	3.3	3.0	3.0	2.0	4.5	2.8	4.0	4.8	4.2	3.9	**3.0**
9-Edge/Top	16.8	16.2	16.1	15.9	15.6	15.3	13.7	15.7	14.2	17.0	18.4	15.8	15.0	**15.8**
10-Edge/Base	16.5	16.3	16.0	15.0	15.7	15.3	13.9	16.0	14.3	16.7	17.2	16.1	15.3	**15.7**
11-Air Probe	17.5	17.4	17.5	17.1	17.0	16.3	14.3	16.2	15.0	17.6	17.9	16.5	16.0	**16.6**


average temps all probes Expt 4
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1-Ce
2-Ce
3-Ce
4-Ed
5-Ed
6-Ce
7-Ce
8-Ce
9-Ed
10-E
11-A
AVG


All data std with ice Expt 4
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
0
5
10
15
20
25
30
35
40
1-Centre/Base
2-Centre/Mid
3-Centre/Top
4-Edge/Top
5-Edge/Base
11-Air Probe


All data "dry chill " Expt 4
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
5
10
15
20
25
30
35
40
6-Centre/Base
7-Centre/Mid
8-Centre/Top
9-Edge/Top
10-Edge/Base
11-Air Probe

5.3.5 EXPERIMENT 5. TO COMPARE TEMPERATURE READINGS INSIDE CANS WITH THOSE IN THE CLOSE ENVIRONMENT

Reason:- All of the previous experiments have shown marked temperature differences within an eski depending upon the position of the probe. Whilst the rate of change of temperature of a lobster to an environment change will differ from that of a can, it was still relevant to determine how representative our external can readings were when compared with the can centre.

Method:- For this experiment a single eski was used. Four cans of tomatoes were pierced through the lid, thermocouple wire inserted into the can and sealed with Araldite. Four pairs of thermocouple wires were taped to the outside with the probes not touching the can wall. These were packed into the eski in similar positions to those used for the previous experiments and a 1kg ice pack included.

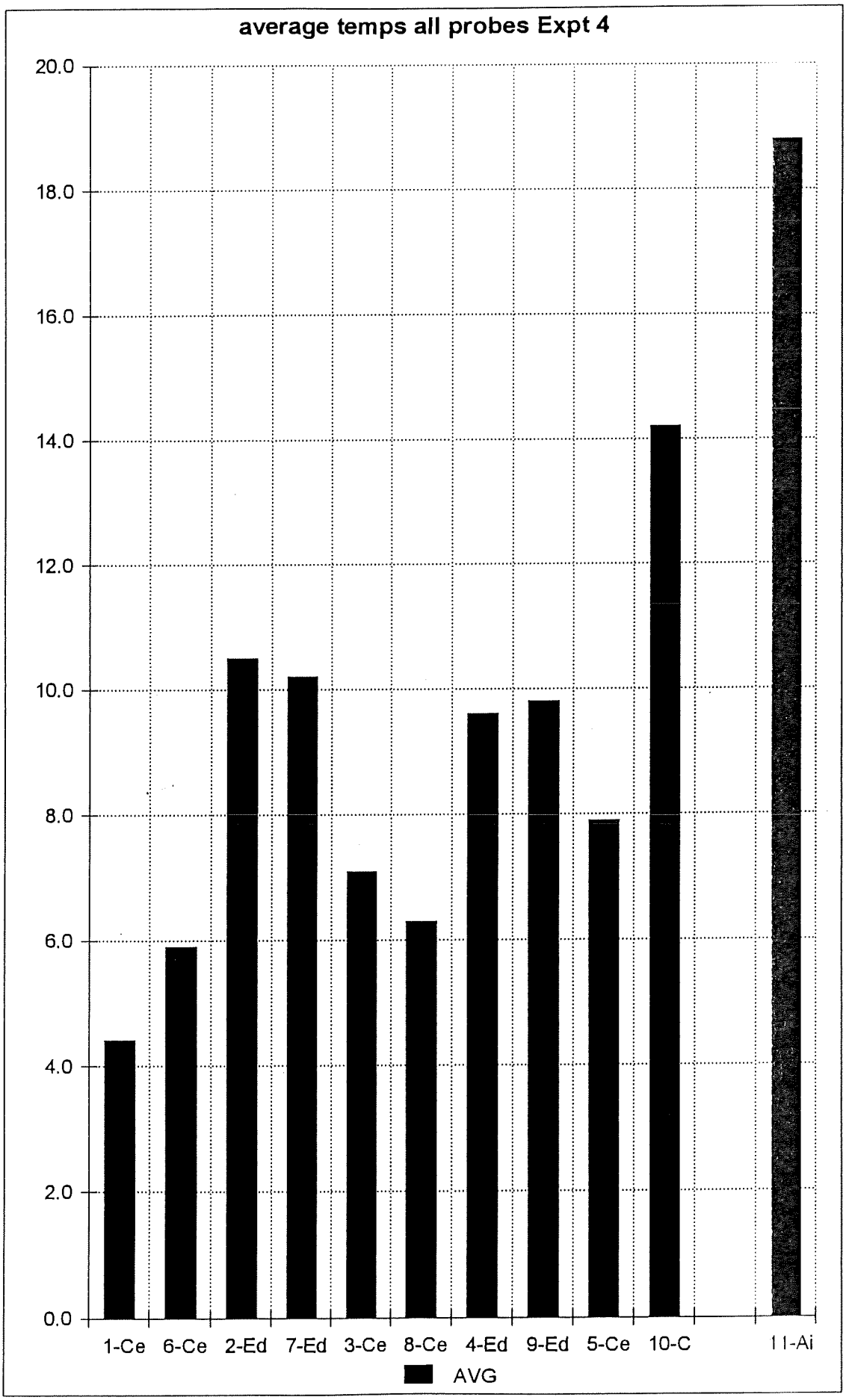
Probe 5 was positioned underneath the eski lid and probe 10 actually inserted into the eski wall.

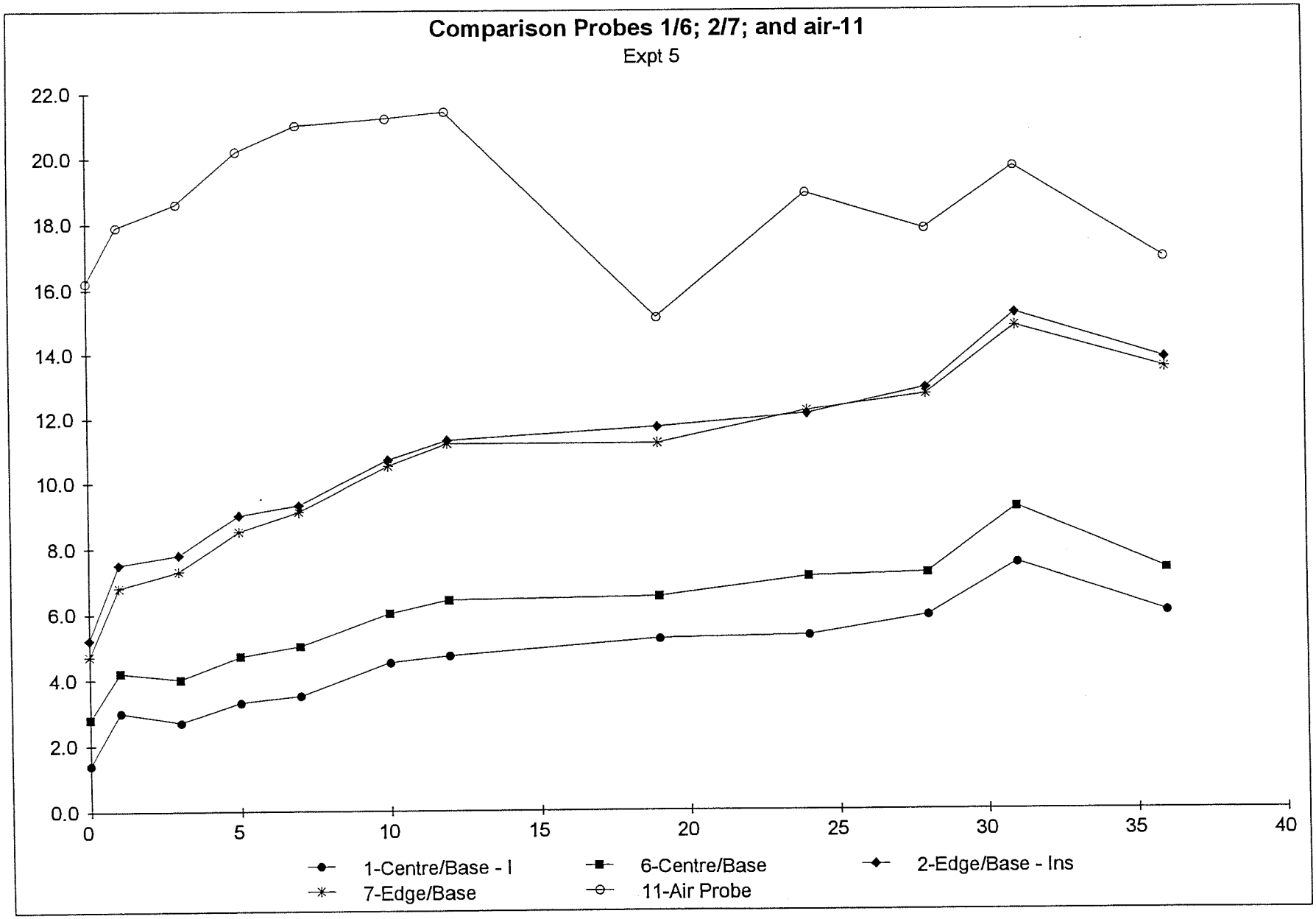
Results:- The average values and individual data plots show very close correlation between the inside and outside can temperature with temperature differences rarely greater than 1°C. These confirm that the temperature gradients measured would be experienced by the lobsters in the live situations.

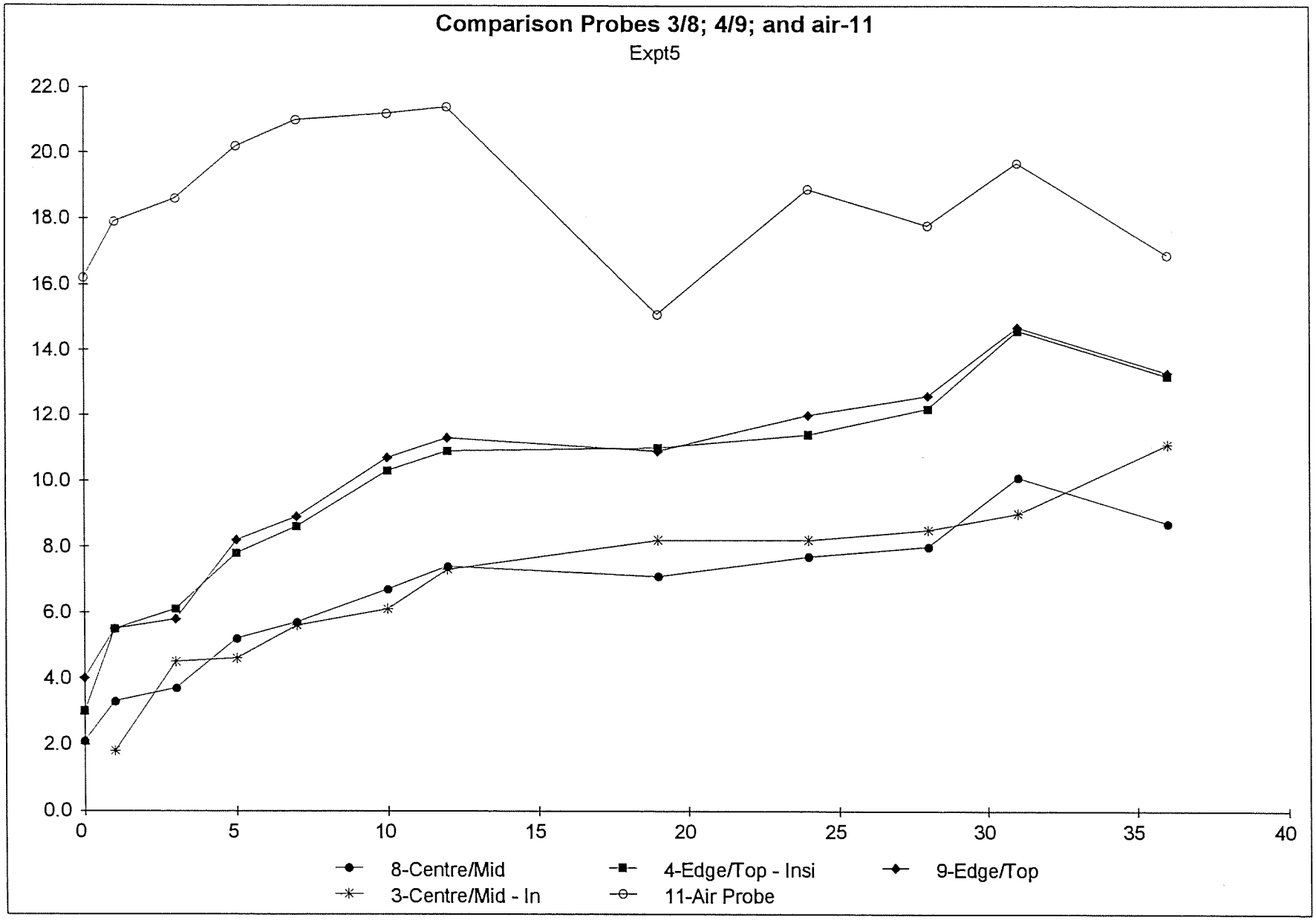
Probe 5 at the top was influenced by the overall temperature of the eski (the cans were very cold when packed) and by the ice pack beneath. Probe 10 was more influenced by the external temperature but there remained a 5°C temperature differential over the first 12 hours.

Experiment 5 - Compare Temperature Readings inside cans with those in close environment

Probe Temps	Time - Hours												
	0	1	3	5	7	10	12	19	24	28	31	36	AVG
1-Centre/Base - Inside can	1.4	3.0	2.7	3.3	3.5	4.5	4.7	5.2	5.3	5.9	7.5	6.0	**4.4**
6-Centre/Base	2.8	4.2	4.0	4.7	5.0	6.0	6.4	6.5	7.1	7.2	9.2	7.3	**5.9**
2-Edge/Base - Inside can	5.2	7.5	7.8	9.0	9.3	10.7	11.3	11.7	12.1	12.9	15.2	13.8	**10.5**
7-Edge/Base	4.7	6.8	7.3	8.5	9.1	10.5	11.2	11.2	12.2	12.7	14.8	13.5	**10.2**
3-Centre/Mid - Inside can	1.8	4.5	4.6	5.6	6.1	7.3	8.2	8.2	8.5	9.0	11.1	9.7	**7.1**
8-Centre/Mid	2.1	3.3	3.7	5.2	5.7	6.7	7.4	7.1	7.7	8.0	10.1	8.7	**6.3**
4-Edge/Top - Inside can	3.0	5.5	6.1	7.8	8.6	10.3	10.9	11.0	11.4	12.2	14.6	13.2	**9.6**
9-Edge/Top	4.0	5.5	5.8	8.2	8.9	10.7	11.3	10.9	12.0	12.6	14.7	13.3	**9.8**
5-Centre/Top	5.1	4.3	5.6	8.3	9.0	9.4	9.9	7.7	8.6	8.3	10.6	7.9	**7.9**
10-Centre/Top - Eski wall	11.2	12.3	12.4	14.3	14.8	15.6	16.2	13.5	14.8	14.4	16.4	14.2	**14.2**
11-Air Probe	16.2	17.9	18.6	20.2	21.0	21.2	21.4	15.1	18.9	17.8	19.7	16.9	**18.8**


average temps all probes Expt 4
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1-Ce
6-Ce
2-Ed
7-Ed
3-Ce
8-Ce
4-Ed
9-Ed
5-Ce
10-C
11-Ai
AVG


Comparison Probes 1/6; 2/7; and air-11
Expt 5
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
5
10
15
20
25
30
35
40
1-Centre/Base - I
6-Centre/Base
2-Edge/Base - Ins
7-Edge/Base
11-Air Probe


Comparison Probes 3/8; 4/9; and air-11
Expt5
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
5
10
15
20
25
30
35
40
8-Centre/Mid
4-Edge/Top - Insi
9-Edge/Top
3-Centre/Mid - In
11-Air Probe

5.3.6 EXPERIMENT 6. TO EVALUATE THE PERFORMANCE OF 'INSUL-BOX' PACKAGING AS AN ALTERNATIVE TO FOAM ESKIS

Reason:- Insul-box is a cardboard carton with a reflective foil coating on both sides. A separate large surface area foil coated ice pack is included. Whilst considerably more expensive than foam eskis the thin walls ensure the pack occupies less space allowing more product to be packed per container. The insulation properties of the pack were unknown and this experiment carried out as an initial evaluation.

Method:- The dimensions of the Insul-box are different to the foam eski being taller and narrower. The probe positions were, thus, not identical in the trial and standard packs. Additionally, the Insul-box ice pack is flat and ideally positioned on top of the shavings under the lid. The two packs were made up with identically chilled cans and room temperature wood shavings.

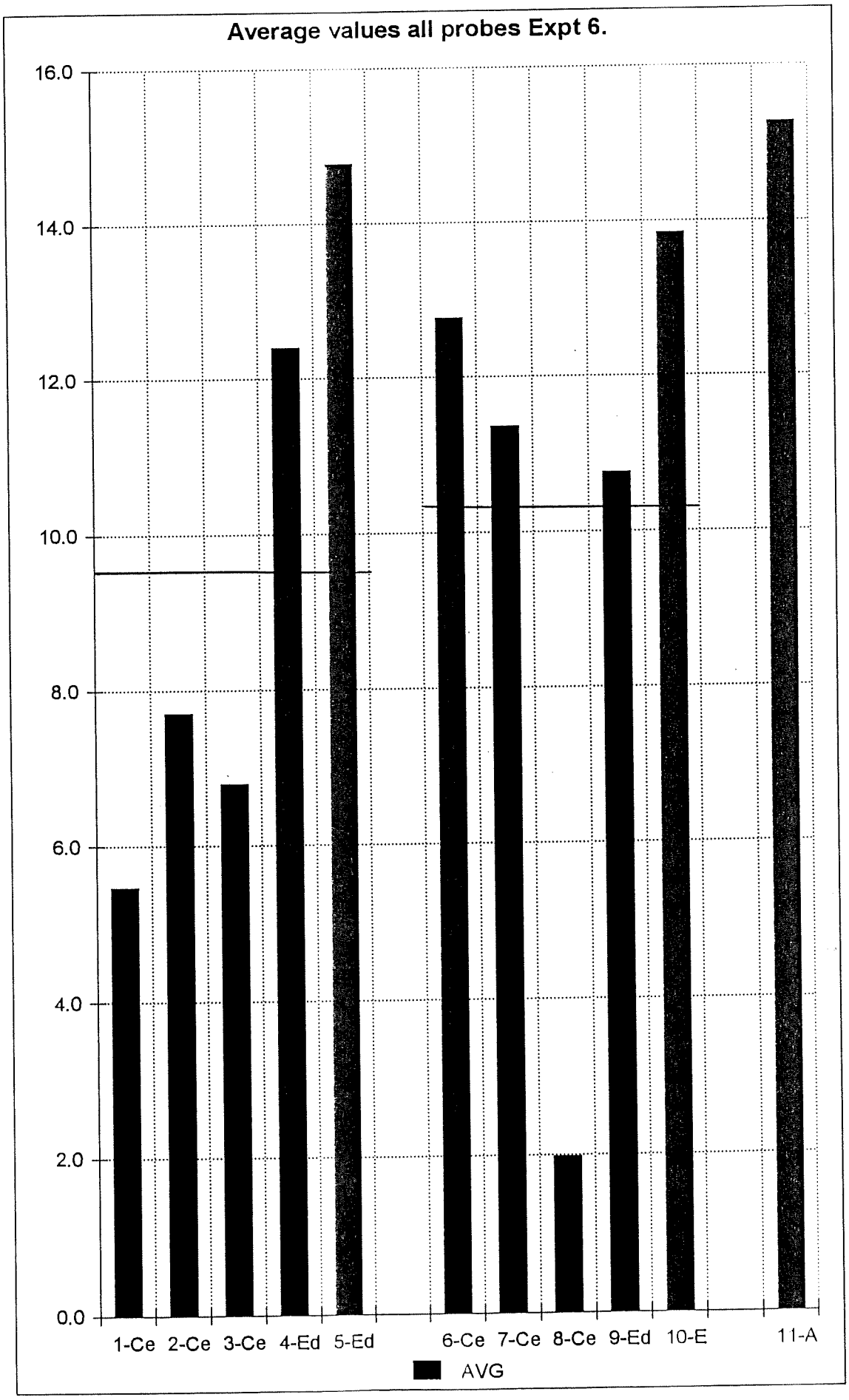
Results:- As the probe positions were different it is less easy to compare the individual results in this experiment. On average the control pack temperature was 9.4°C compared with 10.2°C for the Insul-box. The top probe in the Insul-box pack was close to the ice pack and suggests this had completely thawed between 36 and 44 hours, whereas the indications are that the standard water bottle was still frozen after 44 hours. When removed after 56 hours the water bottle was cold (not frozen) and the Insul-box warm. This is reflected in the temperatures in the Insul-box pack merging at the end.

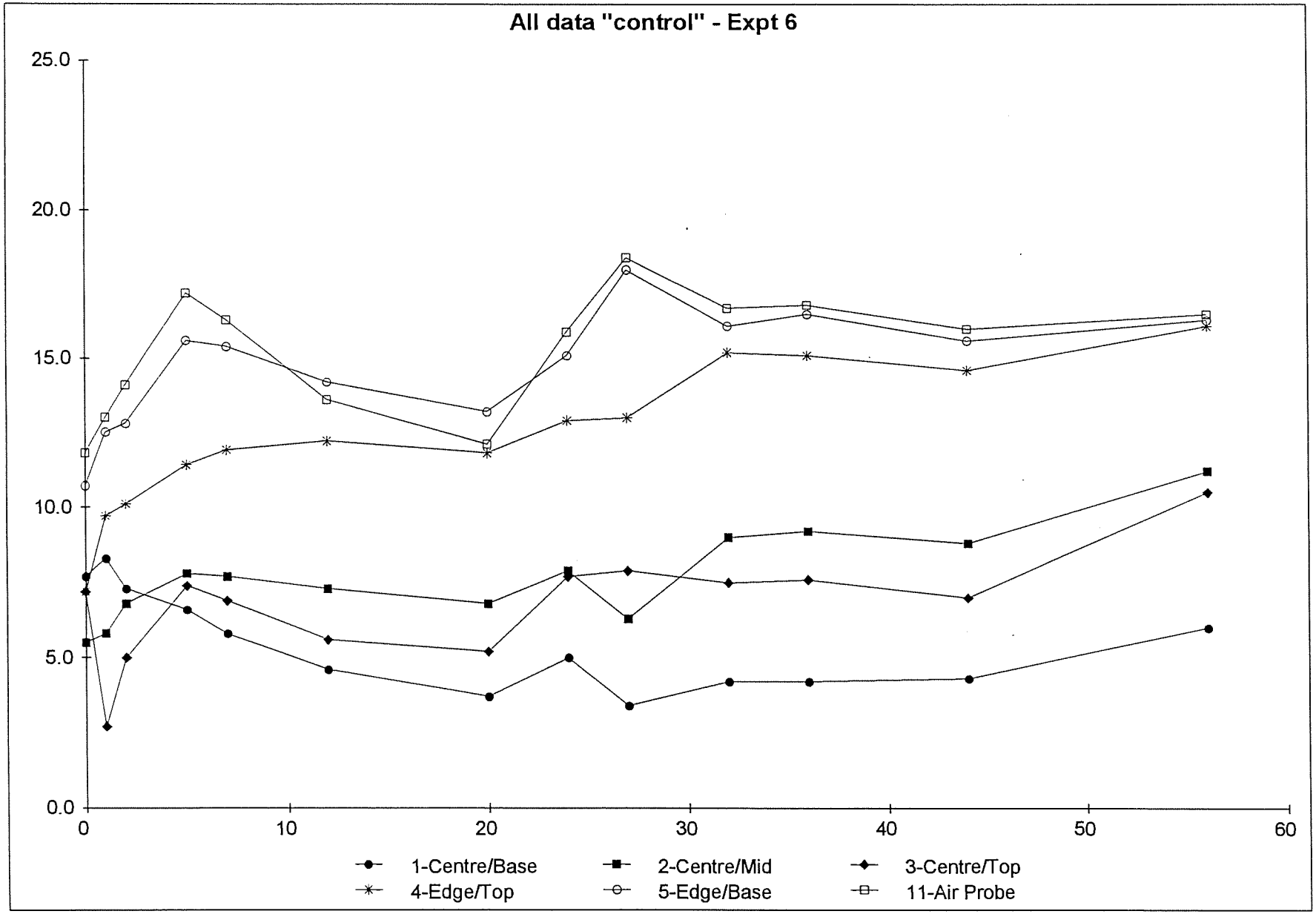
A further trial using an ice bottle in the Insul-box carton would be needed to determine whether the Insul-box ice pack is insufficient or whether the insulation properties are not as good as an eski. The results suggest the Insul-box as supplied would only provide protection for 24 hours under summer conditions, but this may be sufficient. Note the highest ambient temperature recorded in this trial was 18.4°C

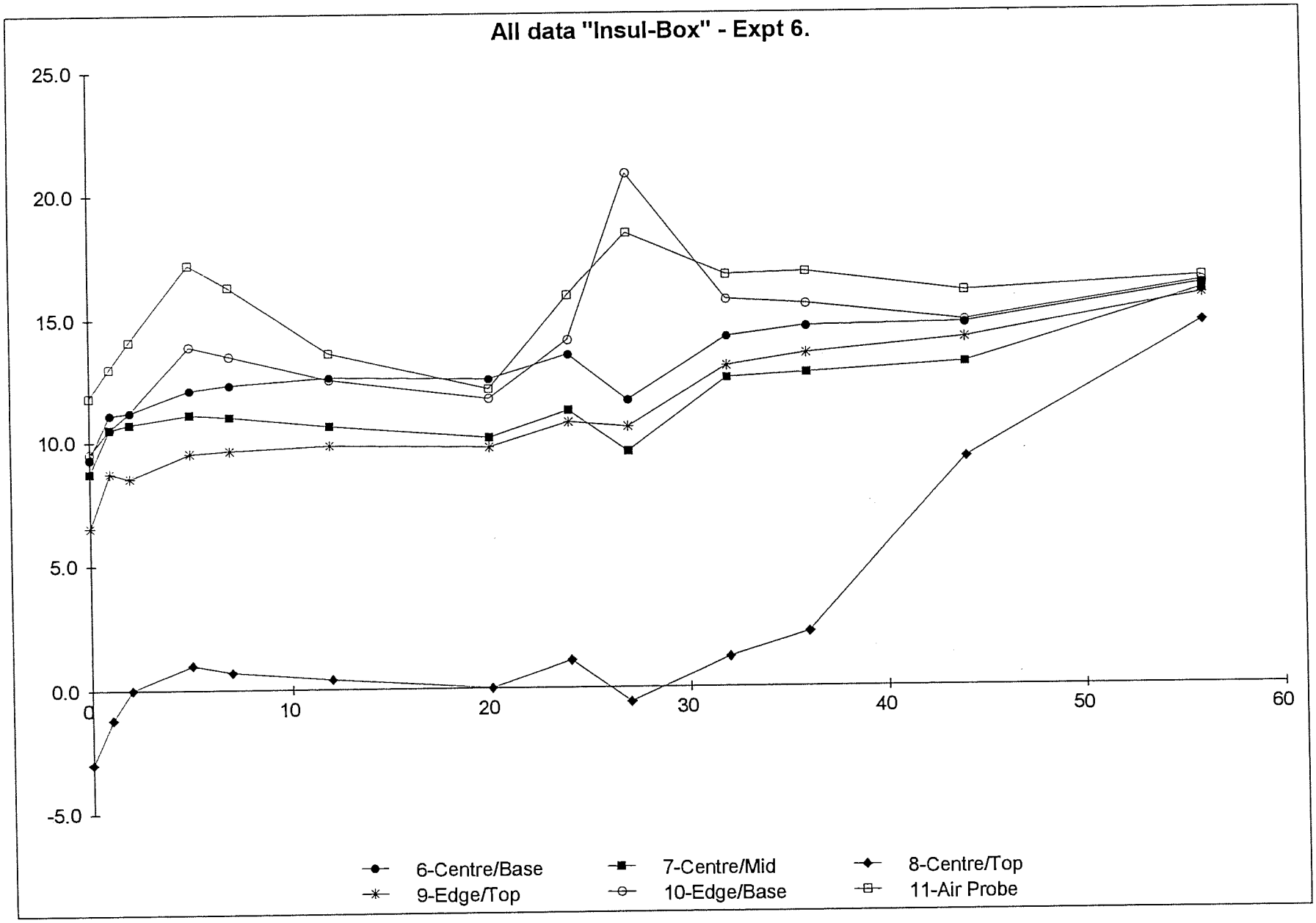
Experiment 6 - To evaluate the performance of "Insul-Box" Packaging.

Probe Temps **Time - Hours**

	0	1	2	5	7	12	20	24	27	32	36	44	56	AVG
1-Centre/Base	7.7	8.3	7.3	6.6	5.8	4.6	3.7	5.0	3.4	4.2	4.2	4.3	6.0	**5.5**
2-Centre/Mid	5.5	5.8	6.8	7.8	7.7	7.3	6.8	7.9	6.3	9.0	9.2	8.8	11.2	**7.7**
3-Centre/Top	7.2	2.7	5.0	7.4	6.9	5.6	5.2	7.7	7.9	7.5	7.6	7.0	10.5	**6.8**
4-Edge/Top	7.2	9.7	10.1	11.4	11.9	12.2	11.8	12.9	13.0	15.2	15.1	14.6	16.1	**12.4**
5-Edge/Base	10.7	12.5	12.8	15.6	15.4	14.2	13.2	15.1	18.0	16.1	16.5	15.6	16.3	**14.8**
6-Centre/Base	9.3	11.1	11.2	12.1	12.3	12.6	12.5	13.5	11.6	14.2	14.6	14.7	16.2	**12.8**
7-Centre/Mid	8.7	10.5	10.7	11.1	11.0	10.6	10.1	11.2	9.5	12.5	12.7	13.1	16.0	**11.4**
8-Centre/Top	-3.0	-1.2	0.0	1.0	0.7	0.4	0.0	1.1	-0.6	1.2	2.2	9.2	14.7	**2.0**
9-Edge/Top	6.5	8.7	8.5	9.5	9.6	9.8	9.7	10.7	10.5	13.0	13.5	14.1	15.8	**10.8**
10-Edge/Base	9.5	10.5	11.2	13.9	13.5	12.5	11.7	14.1	20.8	15.7	15.5	14.8	16.3	**13.8**
11-Air Probe	11.8	13.0	14.1	17.2	16.3	13.6	12.1	15.9	18.4	16.7	16.8	16.0	16.5	**15.3**


Average values all probes Expt 6.
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1-Ce
2-Ce
3-Ce
4-Ed
5-Ed
6-Ce
7-Ce
8-Ce
9-Ed
10-E
11-A
AVG


All data "control" - Expt 6
25.0
20.0
15.0
10.0
5.0
0.0
0
10
20
30
40
50
60
1-Centre/Base
2-Centre/Mid
3-Centre/Top
4-Edge/Top
5-Edge/Base
11-Air Probe


All data "Insul-Box" - Expt 6.
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
0
10
20
30
40
50
60
6-Centre/Base
7-Centre/Mid
8-Centre/Top
9-Edge/Top
10-Edge/Base
11-Air Probe

5.3.7 EXPERIMENT 7. TO EVALUATE THE EFFECTIVENESS OF AN INSUL-BOX ICE PACK IN A FOAM ESKI AND THE EFFECT OF REMOVING THE ICE PACK COMPLETELY ON TEMPERATURE CONTROL WITHIN ESKIS.

Reason:- Experiments to date have shown wide variations of temperatures within the eski, with the 'edge' lobsters little affected by the presence of an ice bottle. The Insul-box ice pack has a very large surface area and may, therefore, provide a more even temperature distribution. Since there is now sufficient data regarding the use of a 1kg ice pack the effect of no ice pack was trialed.

Method:- The two eskis (with air holes) were packed with similarly chilled cans an extra two cans replacing the ice pack in one eski. The other eski had the pre-frozen Insul-box pack positioned beneath the lid and on top of the last layer of wood shavings.

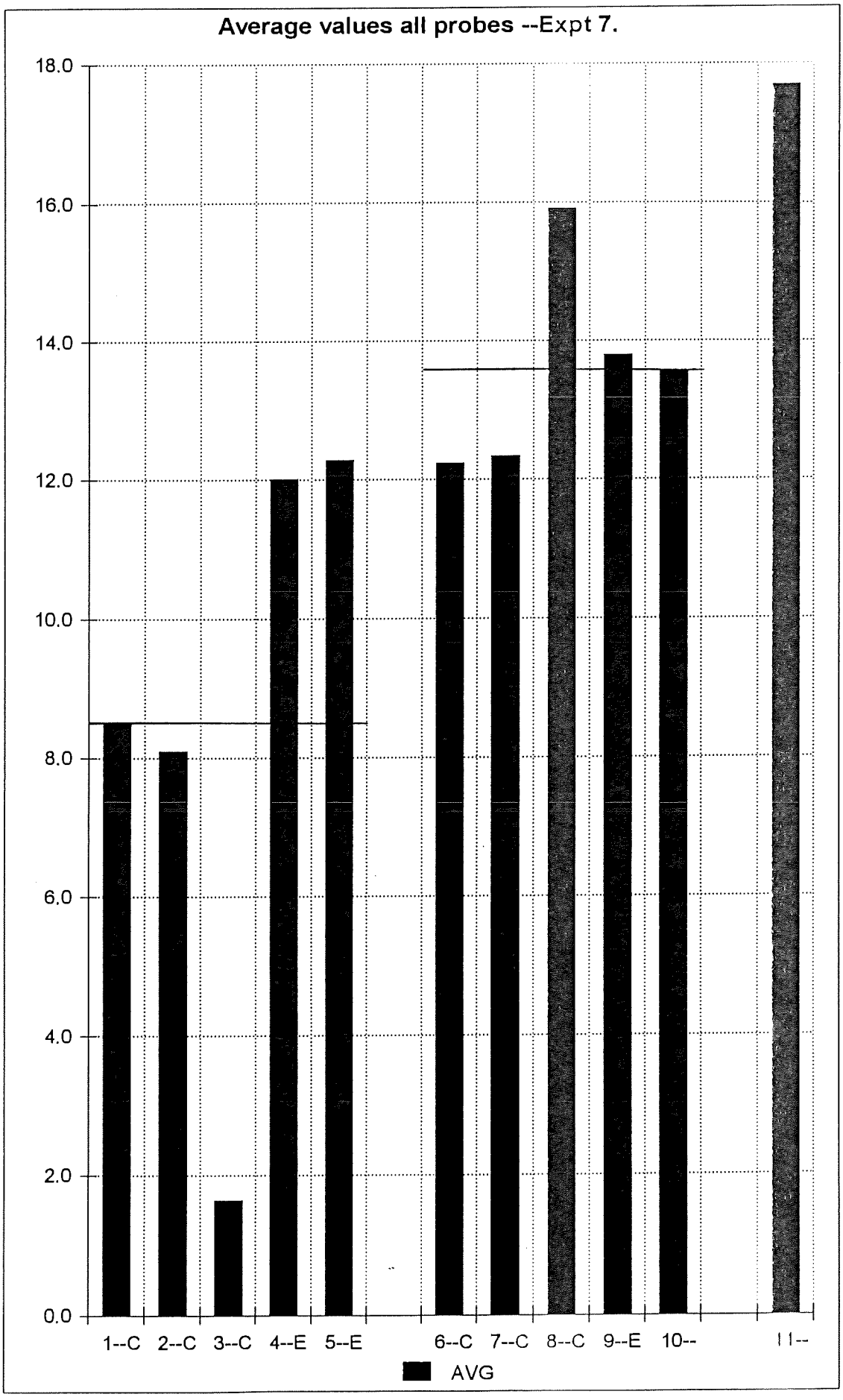
Results:- The insul-box ice pack was just defrosted after 36 hours and, again, the eskis were not subject to particularly hot conditions. Nonetheless comparison of the "all data" graph with previous experiment controls shows a larger temperature difference between 'edge' readings and ambient in this experiment and suggests a stronger influence of the ice pack at the extremities of the eski. Considerable temperature variations within the eski remains.

Naturally there was much less temperature variation in the pack without ice and interestingly the average temperature across the 26 hours was 13.6°, i.e. 4°C less than the average ambient. The results suggest that lobsters packed at 10°C in an eski will maintain temperature between 12 and 20 hours provided the ambient temperature is less than 20°C.

Experiment 7 - Effect of Insul-Box ice pack in std. eski & eski with no ice pack on temps. within eskis.

Probe Temps **Time - Hours**

	0	1	3	6	9	12	20	24	28	32	36	AVG
1--Centre/Base	8.0	7.5	6.6	6.5	9.4	8.5	9.3	8.8	9.3	9.2	10.2	**8.5**
2--Centre/Mid	9.0	8.0	6.7	6.1	8.6	7.5	8.2	7.8	8.5	8.6	10.0	**8.1**
3--Centre/Top	2.8	0.4	-0.7	-1.0	1.6	0.7	0.7	0.1	0.9	4.3	8.2	**1.6**
4--Edge/Top	7.6	7.6	7.1	8.6	12.5	12.7	14.5	14.3	15.2	15.3	16.7	**12.0**
5--Edge/Base	10.1	9.6	8.3	8.7	12.7	12.4	14.2	13.9	14.8	14.6	15.8	**12.3**
6--Centre/Base	10.2	9.8	9.0	9.2	12.6	12.0	14.0	13.8	14.5	14.4	15.1	**12.2**
7--Centre/Mid	10.2	9.8	8.8	9.6	12.6	12.2	13.8	14.1	14.6	14.7	15.3	**12.3**
8--Centre/Top	15.6	13.2	11.8	12.4	17.7	17.1	14.8	18.4	18.4	17.5	18.2	**15.9**
9--Edge/Top	8.2	8.1	8.6	10.0	15.0	15.1	16.2	16.5	17.6	17.7	18.8	**13.8**
10--Edge/Base	11.5	11.0	9.8	10.0	13.6	13.1	15.3	15.5	16.1	16.2	17.1	**13.6**
11--Air Probe	17.2	16.1	14.6	14.6	21.7	20.0	12.7	18.8	21.0	19.2	18.7	**17.7**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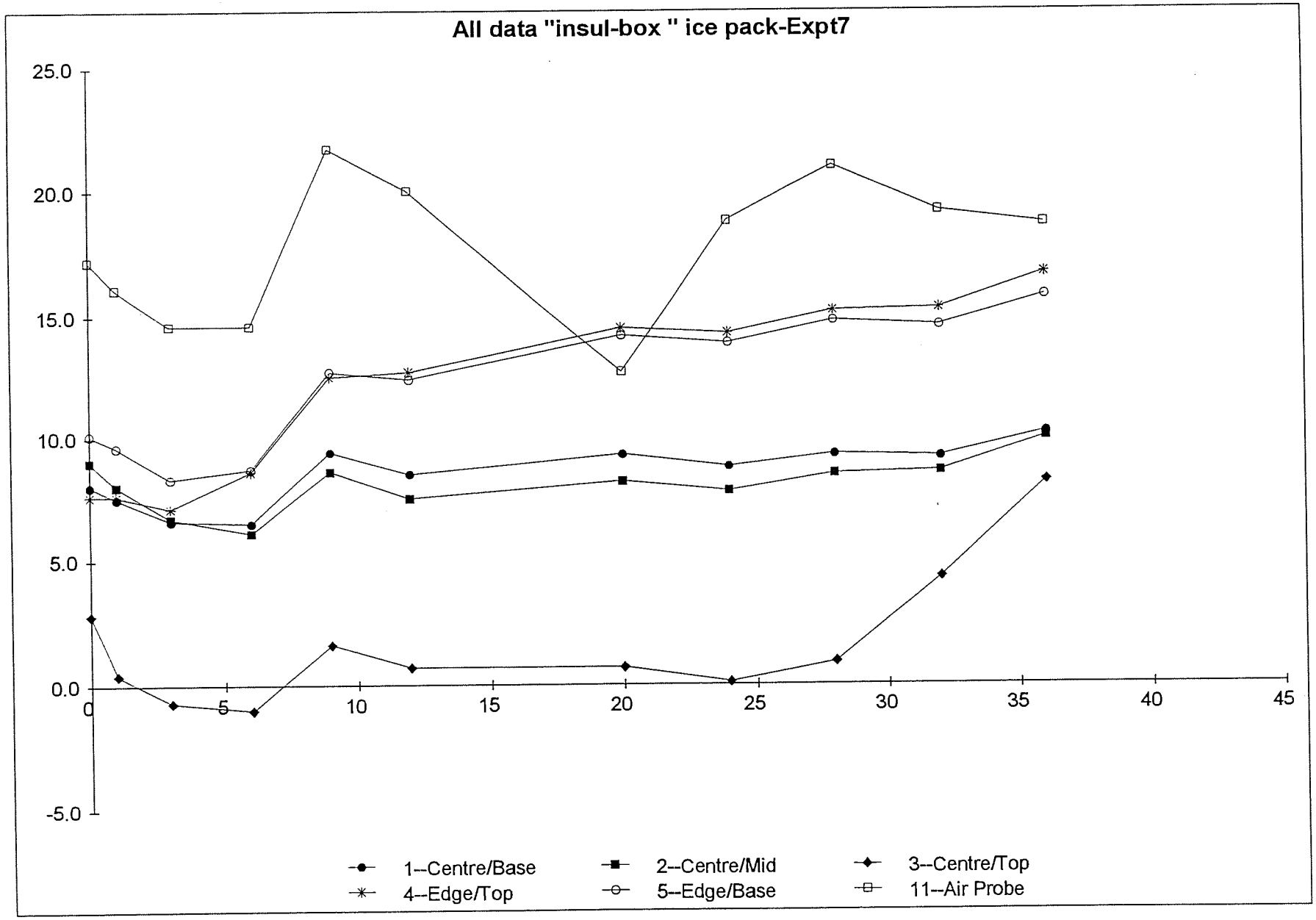
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1--C
2--C
3--C
4--E
5--E
6--C
7--C
8--C
9--E
10--
11--
AVG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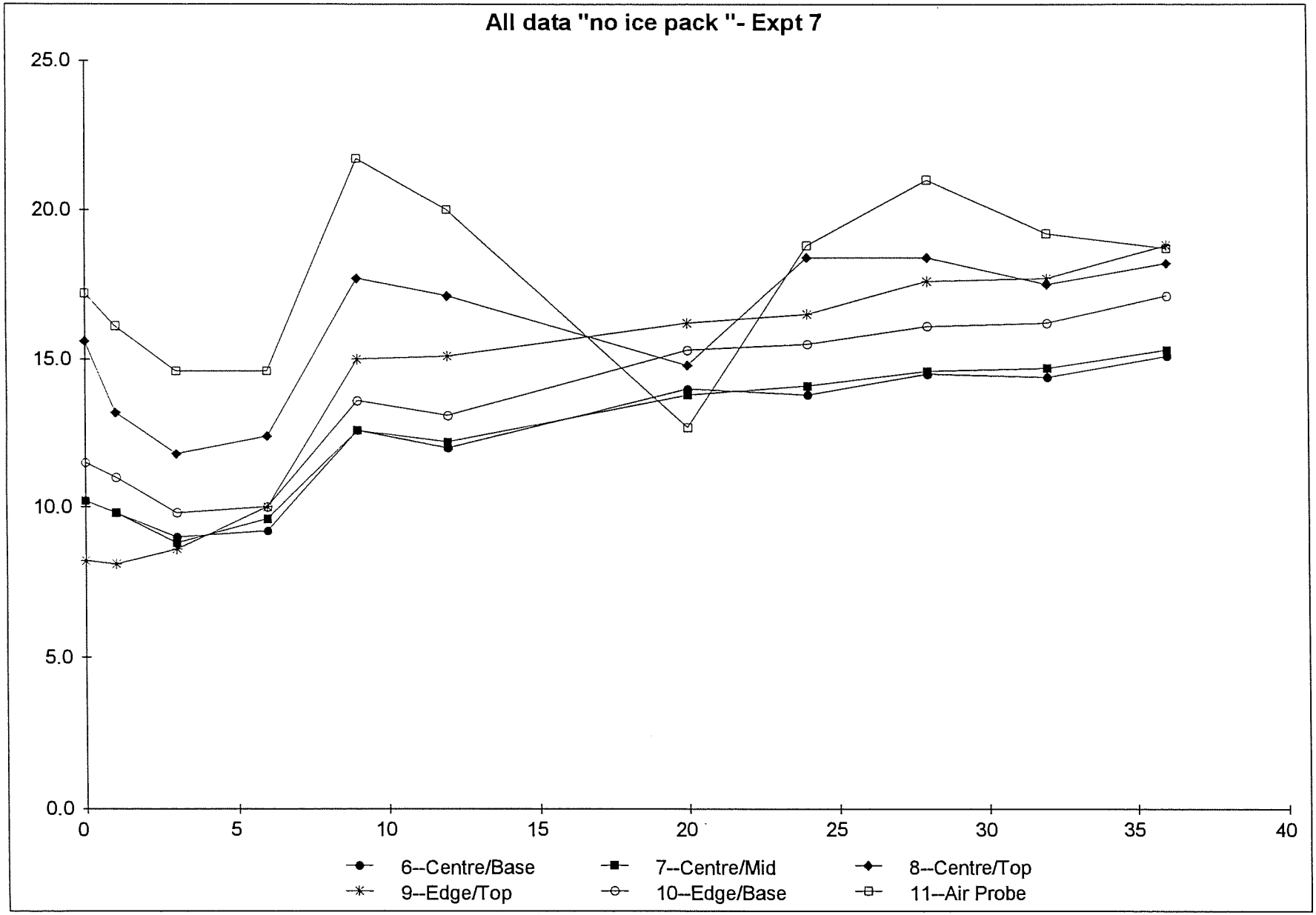
15.0
10.0
5.0
0.0
-5.0
0
5
10
15
20
25
30
35
40
45
1--Centre/Base
2--Centre/Mid
3--Centre/Top
4--Edge/Top
5--Edge/Base
11--Air Probe


All data "no ice pack "- Expt 7
25.0
20.0
15.0
10.0
5.0
0.0
0
5
10
15
20
25
30
35
40
6--Centre/Base
7--Centre/Mid
8--Centre/Top
9--Edge/Top
10--Edge/Base
11--Air Probe

5.3.8. EXPERIMENT 8. TO DETERMINE THE IMPACT OF 2 X 500G ICE BOTTLES SEPARATED IN AN ESKI ON TEMPERATURE DISTRIBUTION AND SIMILARLY ASSESS THE IMPACT USING 2 X 500G DRY CHILL PACKS

Reason:- The results of the previous experiment suggest that spreading the area of influence of the ice packs may reduce variability in internal eski temperature. This experiment was designed to measure any effect using both ice bottles and the dry chill 2000 pre-filled pouches.

Method: The eski contained probes 1-5 was made up with chilled cans and warm wood shavings. 2 x 500g ice bottles were wrapped in paper and packed on the top layer separated towards the two ends of the eski.

The eski containing probes 6-10 was packed similarly, except that the dry chill packs were placed one in the centre at the bottom of the eski and one in the centre at the top.

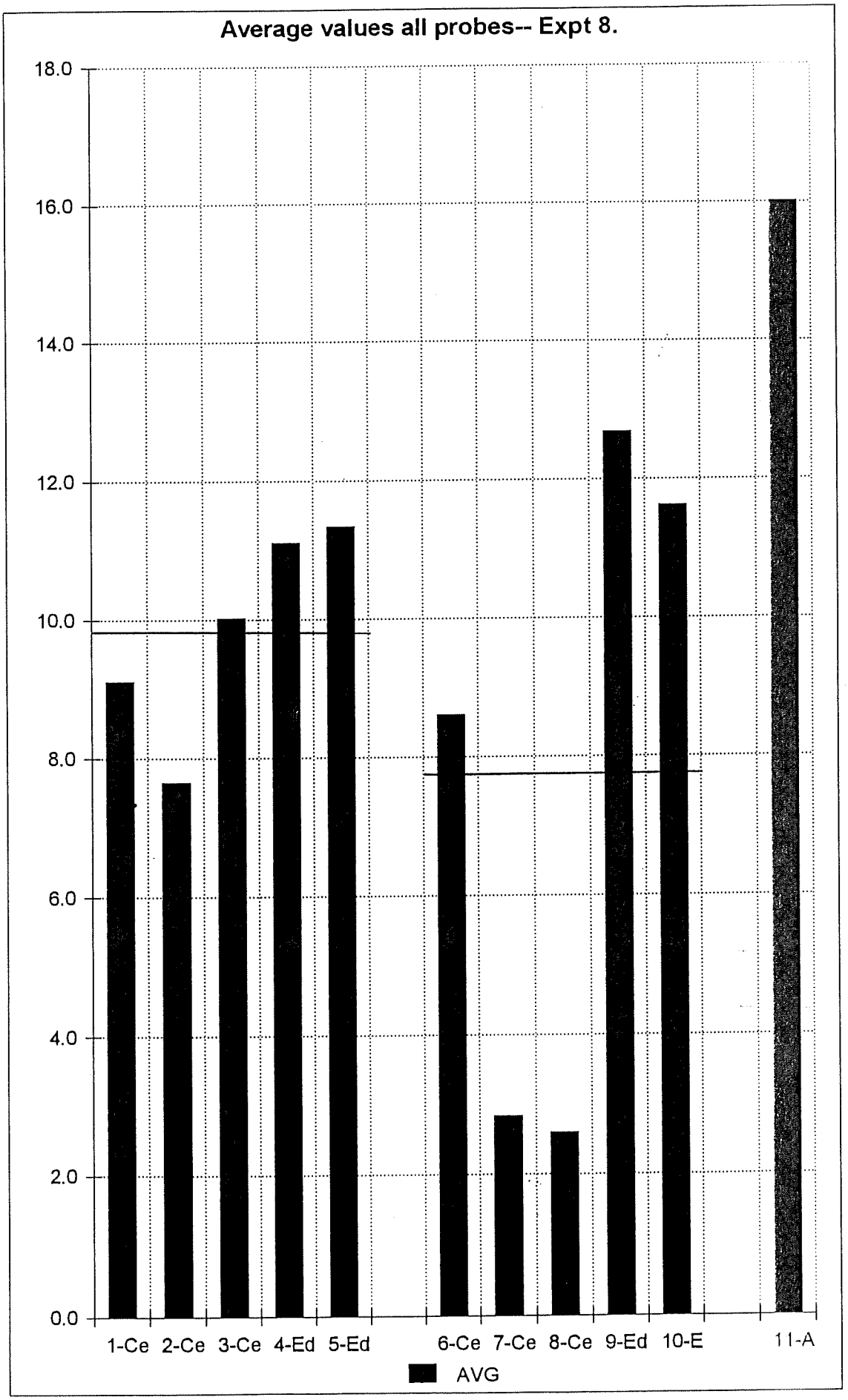
The average temperature across the trial using the two ice bottles was 9.8°C with all individual probe averages little more than 2°C either side of this average. Because the ambient temperatures were low (June/July) the experiment was continued to 58 hours, by which time all ice had melted, but the packs were still cold. The 'all data' plot shows the closer correlation and also the greater differences between the 'edge' probes and ambient.

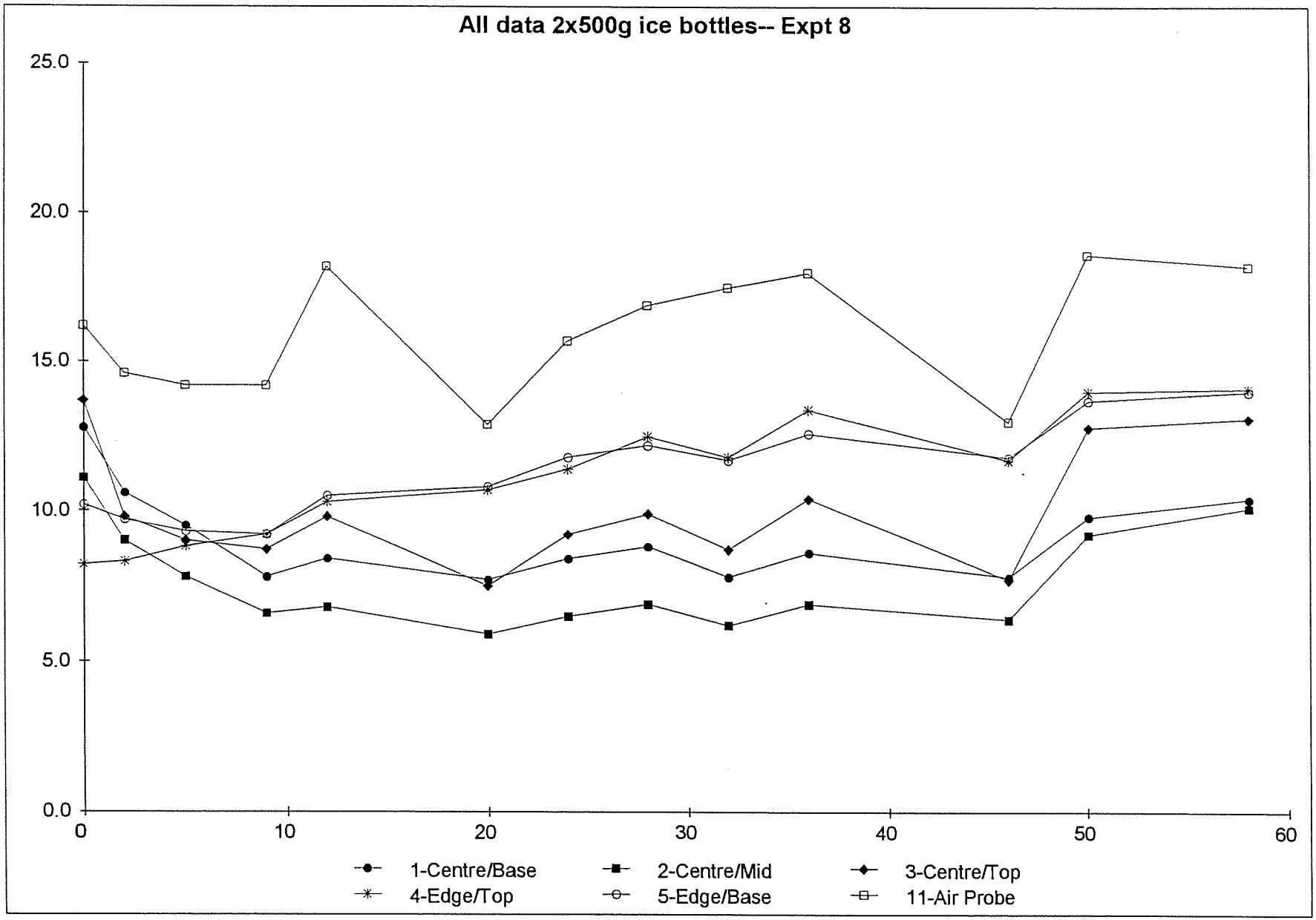
The results using a top and bottom dry chill pack are much more variable with the average edge temperatures - probes 9 and 10 at least 1°C higher than probes 4 and 5. There seemed to be little difference in performance of the dry chill packs compared to the ice packs which is in line with the results from Experiment 4.

Experiment 8 - Effect of 2x500g ice bottles and 2x500g "Dry-Chill" packs separated in eskis.

Probe Temps **Time - Hours**

	0	2	5	9	12	20	24	28	32	36	46	50	58	AVG
1-Centre/Base	12.8	10.6	9.5	7.8	8.4	7.7	8.4	8.8	7.8	8.6	7.8	9.8	10.4	**9.1**
2-Centre/Mid	11.1	9.0	7.8	6.6	6.8	5.9	6.5	6.9	6.2	6.9	6.4	9.2	10.1	**7.6**
3-Centre/Top	13.7	9.8	9.0	8.7	9.8	7.5	9.2	9.9	8.7	10.4	7.7	12.8	13.1	**10.0**
4-Edge/Top	8.2	8.3	8.8	9.2	10.3	10.7	11.4	12.5	11.8	13.4	11.7	14.0	14.1	**11.1**
5-Edge/Base	10.2	9.7	9.3	9.2	10.5	10.8	11.8	12.2	11.7	12.6	11.8	13.7	14.0	**11.3**
6-Centre/Base	10.7	8.9	8.3	7.2	7.5	6.7	7.6	8.2	7.8	8.9	8.5	10.5	11.1	**8.6**
7-Centre/Mid	7.2	4.1	2.7	1.3	1.2	0.0	0.7	1.3	1.0	2.0	2.6	5.5	7.2	**2.8**
8-Centre/Top	2.7	2.7	1.5	0.7	0.5	0.0	0.6	1.3	1.1	2.5	4.2	7.5	8.4	**2.6**
9-Edge/Top	11.4	11.2	10.9	10.9	11.9	11.5	12.3	13.3	13.2	14.9	13.1	15.1	15.2	**12.7**
10-Edge/Base	9.0	8.5	8.7	9.2	10.2	11.1	12.0	12.8	12.7	14.0	13.1	14.8	15.0	**11.6**
11-Air Probe	16.2	14.6	14.2	14.2	18.2	12.9	15.7	16.9	17.5	18.0	13.0	18.6	18.2	**16.0**


Average values all probes-- Expt 8.
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1-Ce
2-Ce
3-Ce
4-Ed
5-Ed
6-Ce
7-Ce
8-Ce
9-Ed
10-E
11-A
AVG


All data 2x500g ice bottles-- Expt 8
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20.0
15.0
10.0
5.0
0.0
0
10
20
30
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50
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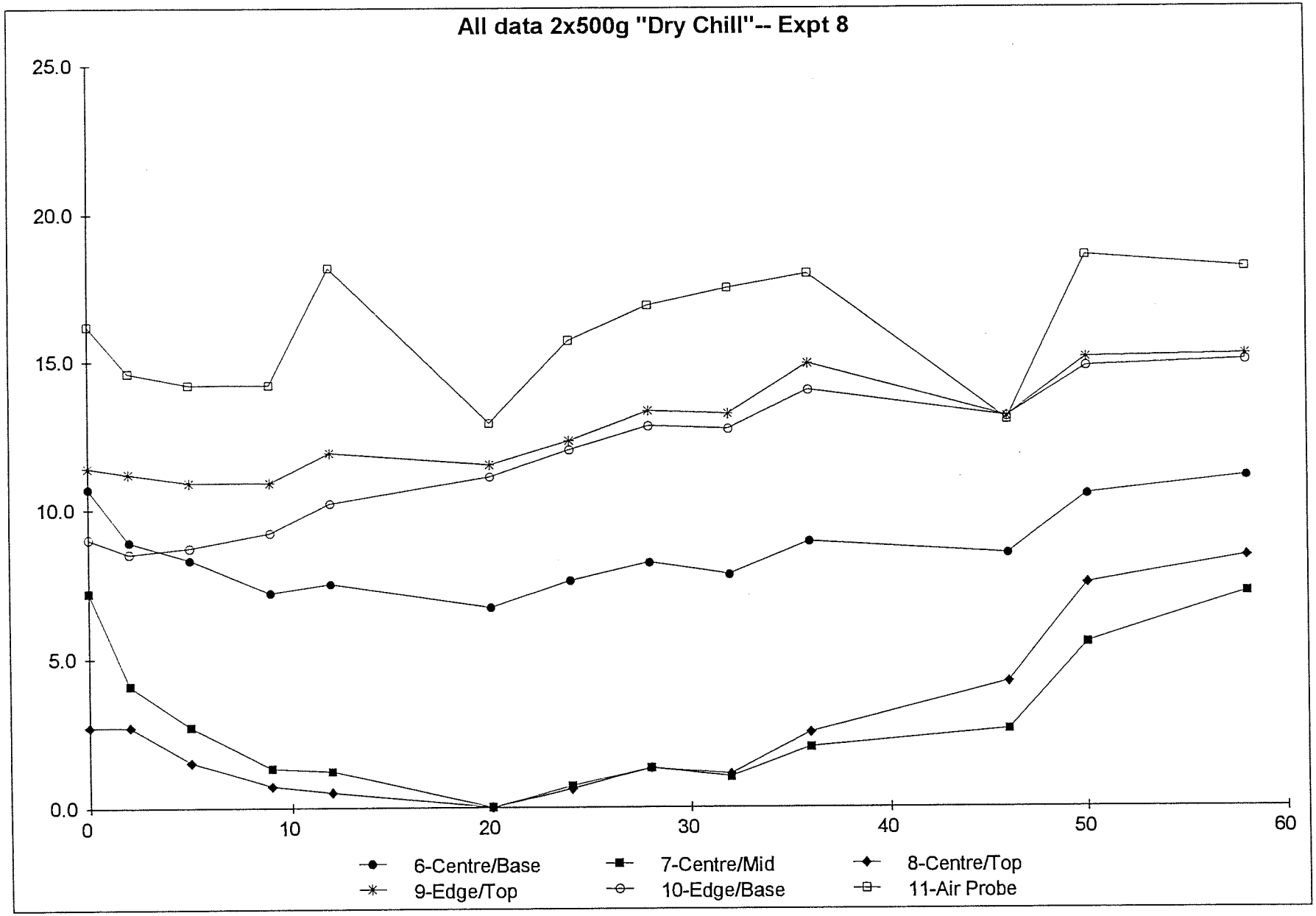
1-Centre/Base
2-Centre/Mid
3-Centre/Top
4-Edge/Top
5-Edge/Base
11-Air Probe


All data 2x500g "Dry Chill"-- Expt 8
25.0
20.0
15.0
10.0
5.0
0.0
0
10
20
30
40
50
60
6-Centre/Base
7-Centre/Mid
8-Centre/Top
9-Edge/Top
10-Edge/Base
11-Air Probe

5.4 SUMMARY AND CONCLUSIONS

The most significant finding from the experiments was the temperature variability within the eskis under the conditions of the trials and thus the wide range of temperatures which the lobsters must withstand to survive.

Three questions for future work are thus :-

1. What is the minimum temperature for survival?
2. What is the maximum temperature for survival?
3. What effect does temperature variation within the max and min range have on survival?

Questions that we considered at the outset to be most relevant were found to be subsidiary to the above, but nonetheless provide useful pointers in optimising packaging with the current level of knowledge.

In the first experiment an effect of air holes on the internal temperature, particularly close to the eski edge, was demonstrated. Other work in the study suggests a need for these holes as their absence actually increased mortality. It would be interesting to know if mortality is highest close to the edge of the eski in high summer.

Conversely, lobsters packed close to the ice bottle experience very low temperatures which may be equally damaging, especially when the temperatures drop towards the end of the season.

Chilling of wood shavings (Experiment 2) has little impact on overall internal temperatures, whilst the pre-chilling of the lobsters (Experiment 3) has a marked effect. The answer to question 1 above would determine the ideal temperature for packing.

Bottled water frozen as ice or proprietary products such as Dry Chill will help to keep the product cooler than would be the case where chilled lobsters are packed without a coolant (Experiments 4 and 7). The sphere of influence of the ice packs is localised and the results from Experiments 7 and 8 suggest that a thin ice pack covering the top surface or two smaller ice bottles packed on the top layer towards each end of the eski will minimise the temperature fluctuations and help protect lobsters from external temperature influence. This requires further work to establish the ideal position and whether the ice packs would remain frozen during the extremes of summer heat.

Experiment 5 confirmed the validity of using point readings as indicators of the actual temperatures experienced by lobsters although the rate of change of lobster temperature in response to external changes would, again, be a useful piece of information.

The one experiment using Insul-box (Experiment 6) suggests it is not as effective as a conventional eski in protecting against temperature variation, but under 'normal' conditions this may not be important. The experiment does highlight the relative crudeness of existing packaging techniques in maintaining temperature. Ice bottles take up valuable space and

weight, whilst the eski, although light, is not a very effective insulator. This may be the most cost effective single use packaging system, but a more detailed study of alternatives is recommended.

The Insul-box reduces space wastage, but is not easy to pack or handle; handling of eskis, particularly by air-line staff, is an important factor in the overall equation. Would 'unitised' loads help and should these be foil wrapped for extra protection?

Whilst the simulation experiments have, perhaps, raised more questions than they have answered accurate control of lobster temperature and more even distribution of coolant in eskis can be carried out immediately while answers to the more fundamental questions are sought.

6 SIMULATION EXPERIMENTS, Lobsters - Effects of packaging materials, holes and water bottle size.

6.1 Introduction

The rock lobster is a marine animal which has the capacity to survive aerial exposure. Stress is likely to be the major influence upon this capacity and two of the most important stressors are temperature and relative humidity. Stress influences the metabolic rate of the rock lobster at levels proportional to the size of the individual.

Aquatic animals exist in a 100% humid environment where they breath by constantly beating water up under the carapace and over the gills. They cannot absorb oxygen from the air unless relative humidity is greater than 70%. High humidity provides moisture in the air in which oxygen dissolves. This allows some ventilation to occur by passing the moist air over the gills instead of water. Environments with a relative humidity of less than 70% do not provide enough moisture to meet the dissolved oxygen requirements of these animals. Packaging systems for lobsters should attempt to maintain low temperatures and provide a relative humidity of greater than 70%.

This research segment evaluates the current packaging system (insulated foam box with holes, wood-shavings and 1000ml ice bottle) in terms of its management of temperature and relative humidity. Experiments compared packaging materials (burlap, woodwool, foam sheets and wood-shavings), the size of the ice bottle (500ml v 1000ml) and the presence or absence of holes.

6.2 Materials and Methods

8 experiments were conducted using four boxes of rock lobsters packed by lobster processing personnel, a control, and three identical test replicates containing 8 - 15 lobsters, depending on size. Experiments were conducted over a period of 54 hours, to simulate the environmental conditions over the longest transport time period for a shipment of lobsters from Geraldton to Japan, ie 30 hours transport time (taking into account delays), with a 24 hour recovery period in a seawater tank.

The 30 hour experimentation period included;

1. 1 hour in a Fremantle rock lobster processing facility (packout plus loading onto truck interval);
2. 6 hours' placement of the 4 boxes into a refrigerator set at 3 - 4°C to simulate travel from Geraldton to Perth in a refrigerated truck;
3. 8 hours placement of the 4 boxes into a hot house at around 33°C to simulate the waiting period prior to aircraft departure in summer time;
4. 8 hours in refrigerated conditions of 3-4 °C to simulate the flight conditions in the cargo hold on the flight to Japan;
5. 5 hours in a hot house at 33°C to simulate conditions on arrival at Japanese airport, transport to holding facility, and unpacking prior to placement in a customer's seawater tank;
6. The remainder of the 30 hour period covered the transport time between refrigeration at processing facility at Fremantle and hot house facilities at Bentley. (The lengths of time mentioned above did vary marginally depending on access to the processing facility).

At the end of the 30 hour test period, the lobsters were unpacked and their health status evaluated as being either strong, weak or dead, by senior lobster processing staff. The temperature and ice content of the ice bottles was also recorded. The live lobsters were colour-coded using nail polish to identify them with a certain test condition and released into tanks. The health status of each animal was similarly assessed after 24 hours.

At the commencement of each trial, Hobo data loggers for temperature, humidity and pressure were included in some boxes. These gave an indication of the environmental changes within the boxes when packed using different materials.

Five trials were undertaken using wood-shavings as the packaging material and comparing:

- no holes, 1000ml ice bottle
- no holes, 500ml ice bottle
- two holes, 500ml ice bottle.

In each of these experiments, a control (standard foam box with one hole punched in either end, and packed with room temperature wood-shavings and a 1000ml ice bottle) was used. The control equated with the most commonly used packaging system for the 1993/94 season.

The other three trials used a control of 500ml ice bottle, no holes and wood-shavings. All replicate test boxes used 500ml ice bottles and no holes in the foam box, and compared three further packaging material types:

- foam
- hessian (burlap)
- woodwool.

Statistical Testing**

The control and replicate test boxes were tested for independence of the health of the lobsters against access to additional air supply provided by a two hole modification to the box, using a G-test of independence, with Yates correction for continuity (used with small sample sizes). The independence level G value is compared with critical values of the Chi-square distribution (df = 1).

	Strong	Weak/Dead	Total (Sum of)
Control	a	b	a + b
Test Total	c	d	c + d
Total (sum of)	a + c	b + d	a + b + c + d = n

** Sokal, R.R, and Rohlf, F.J. (1981) Biometry. 2nd Edition, W.H Freeman and Company. (Tests of independence: two-way tables), pg 731 - 747.

6.3 Experiment 1: Control (1000ml ice bottle, 2 holes) v's 1000ml ice bottle, No holes

6.3.1 Results

Health Status

All lobsters in the control box survived the 30 hour simulation experiment and had 100% health status immediately after unpacking. Four lobsters in the test boxes died during the simulation, though the surviving lobsters were all healthy (Table 6.3.1a). After the 24 hour recovery period in the seawater tank, one lobster from the control box and two lobsters in the test replicates had weakened (Table 6.3.1b).

Table 6.3.1a Health Status of lobsters immediately after unpacking, from the control box (1000ml, 2 holes) and from the replicated test boxes (1000ml, No holes).

	Strong	Weak	Dead	Total	Strong %	Survival %
Replicate 1	11	0	3	14	79	79
Replicate 2	14	0	0	14	100	100
Replicate 3	14	0	1	15	93	93
Total	39	0	4	43	91	91
Control	14	0	0	14	100	100

Table 6.3.1b Health Status of lobsters after 24 hours recovery in seawater tanks, from the control box (1000ml, 2 holes) and from the replicated test boxes (1000ml, No holes).

	Strong	Weak	Dead	Total	Strong %	Survival %
Replicate 1	9	2	3	14	64	79
Replicate 2	14	0	0	14	100	100
Replicate 3	14	0	1	15	93	93
Total	37	2	4	43	86	91
Control	13	1	0	14	92	100

Statistical testing (G-test of independence with Yates correction of continuity, at 5% level) of the strong lobsters against weak and dead lobsters found no significant difference, either immediately after unpacking (independence level G = 0.386) or after a 24 hour recovery period in a seawater tank (independence level G = 0.043).

Environmental Factors

Temperature in the flow-through tanks and the chilled water bath at 0400 hours when packing occurred was 16.0°C and 10.4°C respectively. Most lobsters were immobile when packed caused by their metabolic rate being lowered from being placed in the chilled water bath. Some lobsters were not left in the chilled water for a long enough period to chill them sufficiently thus were still active when packed.

The ambient temperature during the experiment ranged from 3.00°C - 32.25°C (Figure 6.3.1a). The control box (1000ml, 2 holes) had a temperature range of 5.75°C - 26.25°C, while two of the test boxes (1000ml, no holes) showed a temperature range of 6.75°C - 23.25°C and 6.50°C - 23.50°C (Figure 6.3.1a).

The relative humidity logger unfortunately malfunctioned and did not work within the control box. The test box logger maintained a relative humidity of greater than 100% after the first eight hours. This suggested that the logger came in contact with water. The lowest recording of relative humidity within the box (82%) was immediately after closing the lid (Figure 6.3.1b).

Pressure recorded in one of the test boxes during the simulation showed pressure decreasing to 1026 mbars and increasing to 1039 mbars within the closed system (polystyrene box with no holes) (Figure 6.3.1c). This occurred proportionately to the ambient temperature fluctuations.

The temperature of the water inside the ice bottles and the ice content left after the 30 hour simulation experiment, showed the control box ice bottle having a slightly higher temperature and slightly less ice content.

Table 6.3.1c The ice content and temperature of the water inside the ice bottles from each treatment after the 30 hour simulation experiment. (*The ice was very porous. Percentage determined by bulk, not liquid.)

1000ml	Ice Bottle °C	Ice Content %*
Replicate 1 (No holes)	-2.3	20.0
Replicate 2 (No holes)	-1.9	10.0
Replicate 3 (No holes)	-2.0	15.0
Control (2 holes)	-1.6	5.0

6.3.2 Discussion

The proportion of strong lobsters was independent of the number of holes in the packing box, even though the presence of holes in the control box allowed greater fluctuation in temperature. The relative humidity within the test box remained higher than 82% throughout the 30 hour simulation, thus, the 1000ml ice bottle and no holes provided a suitably humid environment for the lobsters to carry out some oxygen exchange in air.

In terms of the statistical significance of the results obtained here, there is no significant benefit in having holes in either end of the foam box (when packaging 14-15 lobsters in the foam box with wood-shavings and a 1000ml ice bottle).

The percentage of survival in the test boxes (ave: 91%) was not acceptable on an industry basis which requires a survival of 95%+. The control box survival (100%) was acceptable. Thus, this study is inconclusive as to whether holes are necessary to enhance survival. The elimination of holes from the current packaging system does not seem to be a valid option, taking into account current post-harvest handling procedures. Further research is required to investigate the necessity for holes to be punched into boxes and as to the function they perform eg, gas exchange.

Figure 6.3.1a Ambient temperature and temperatures inside the control box (1000ml ice bottle, 2 holes) and replicated test boxes (1000ml ice bottle, No holes), during the 30 hour simulation experiment.

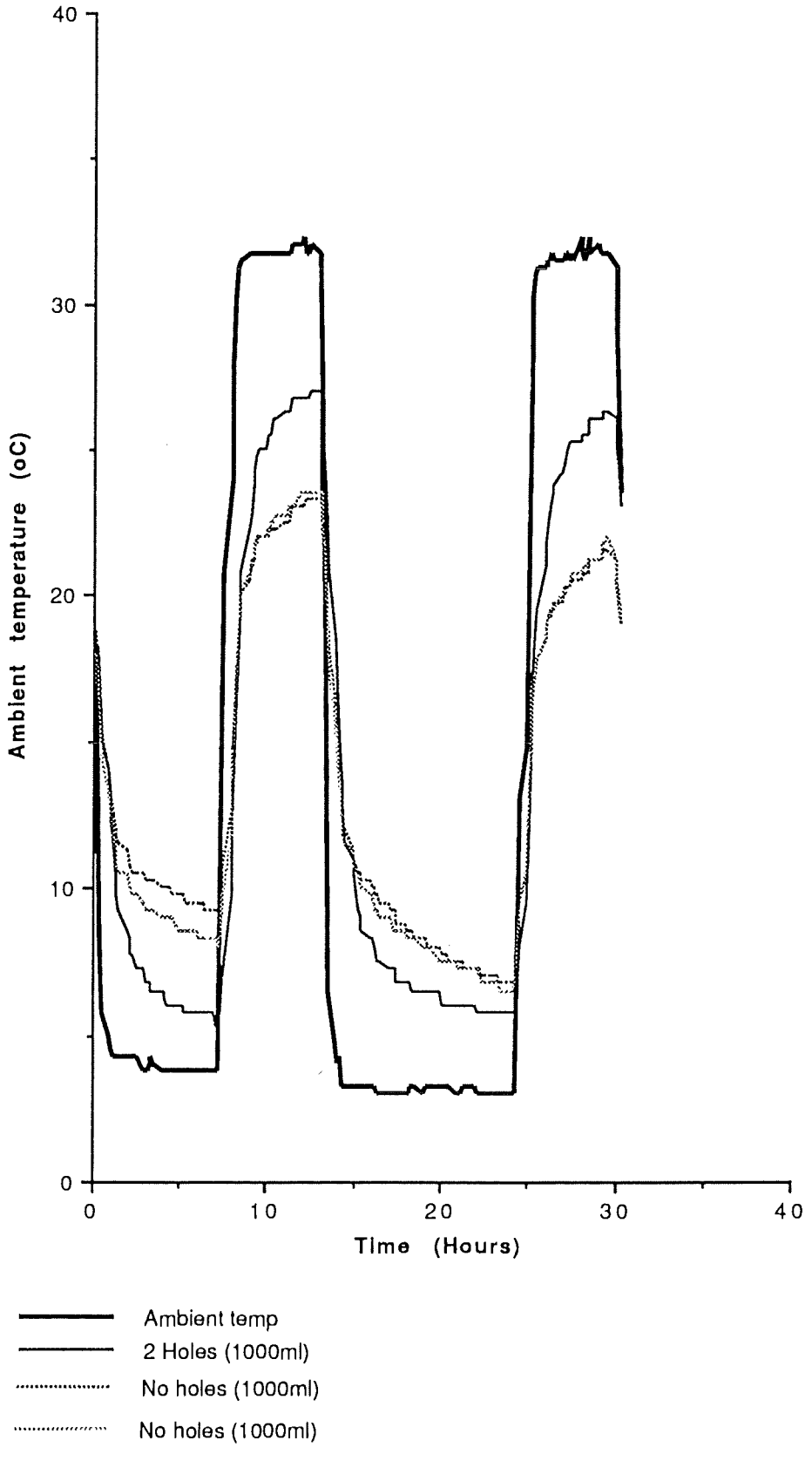


Figure 6.3.1b Relative humidity (%) recorded in one of the replicated test boxes (1000ml ice bottle, No holes) during the 30 hour simulation experiment.

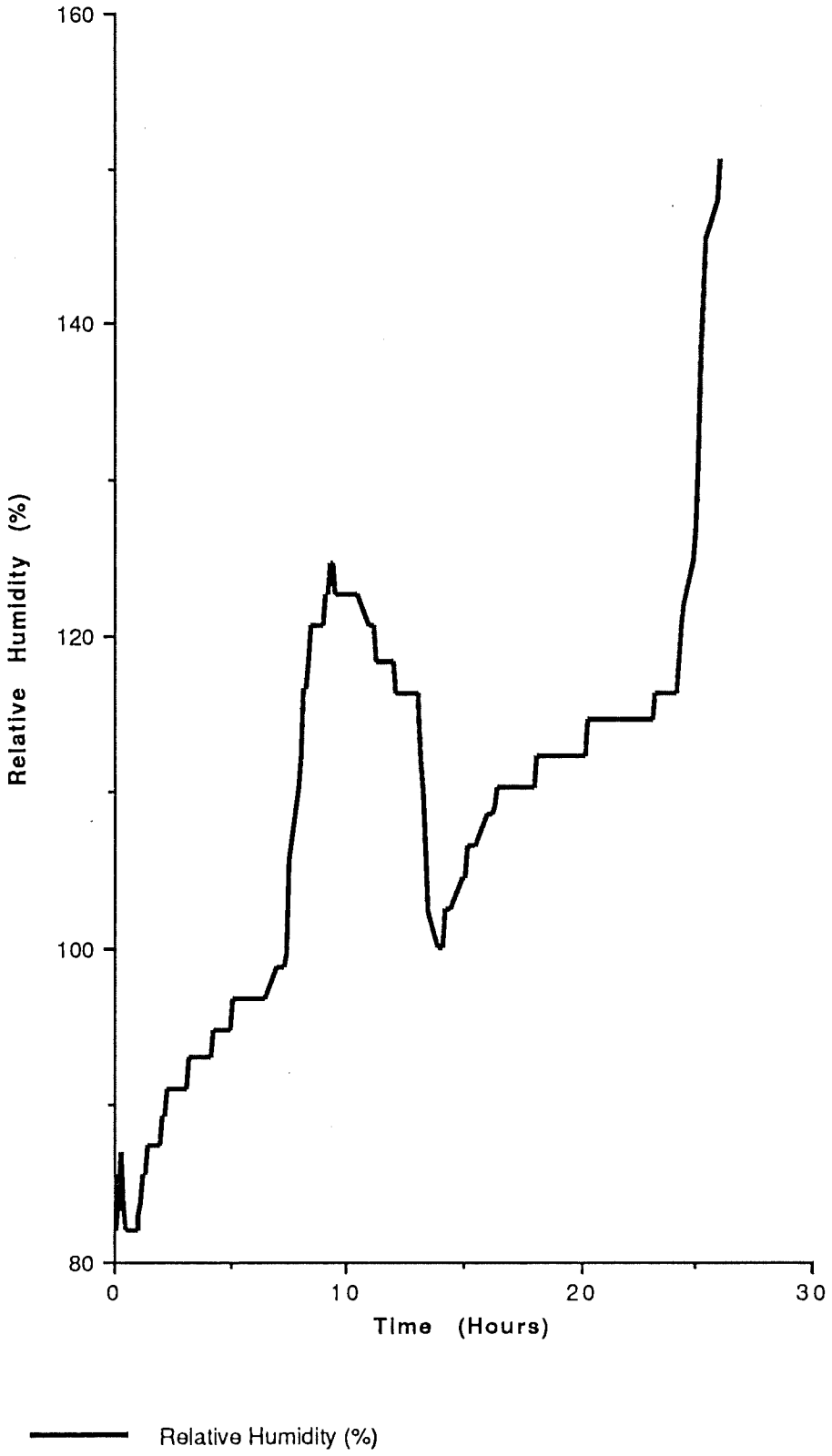
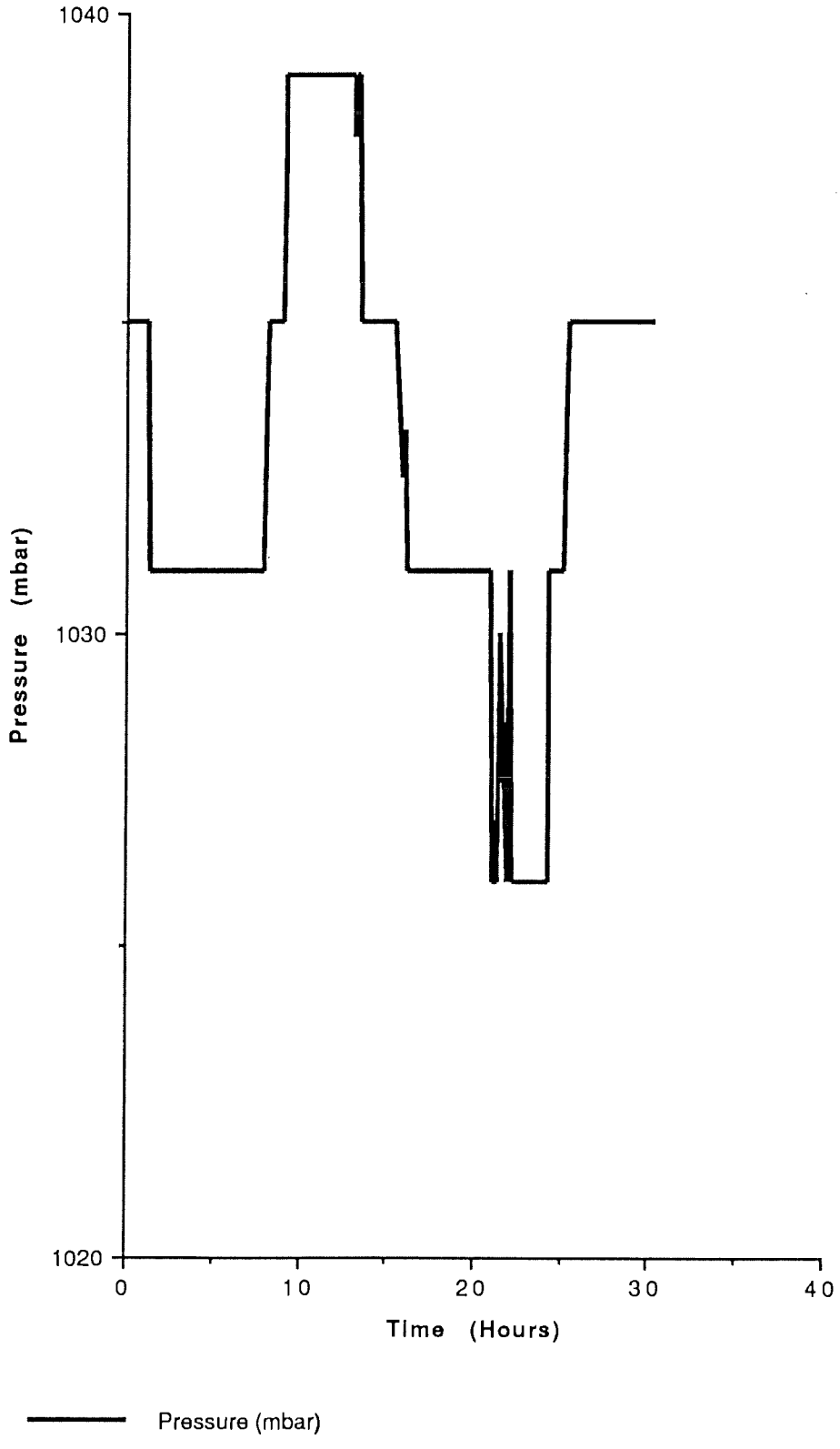


Figure 6.3.1c Pressure (mbar) recorded in one of the replicated test boxes (1000ml ice bottle, No holes) during the 30 hour simulation experiment.



6.4 Experiment 2: Control (1000ml ice bottle, 2 holes) v's 500ml Ice Bottle, 2 holes

6.4.1 Results

Health Status

The lobsters had 100% survival and 93% health status in both treatment groups after the 30 hour simulation experiment (Table 6.4.1a). After the 24 hour recovery period in a seawater tank (Table 6.4.1b), the health status of the control box lobsters had not altered, though two lobsters from the replicated test boxes regained health status, allowing two test boxes to have a better health status than the control box.

Table 6.4.1 Experiment One: Heath status of lobsters immediately after unpacking, from the control box (1000ml, 2 hole) and from replicates of the test box (500ml, 2 holes).

	Strong	Weak	Dead	Total	Strong %	Survival %
Replicate 1	15	0	0	15	100	100
Replicate 2	12	2	0	14	86	100
Replicate 3	13	1	0	14	93	100
Total	40	3	0	43	93	100
Control	13	1	0	14	93	100

Table 6.4.1b Health Status of lobsters after a 24 hour recovery period in a seawater tank, from the control box (1000ml, 2 holes) and from replicates of the test box (500ml, 2 holes).

	Strong	Weak	Dead	Total	Strong %	Survival %
Replicate 1	15	0	0	15	100	100
Replicate 2	13	1	0	14	93	100
Replicate 3	14	0	0	14	100	100
Total	42	1	0	43	98	100
Control	13	1	0	14	93	100

Statistical testing (G-test of independence with Yates correction of continuity, at 5% level) of the strong lobsters against weak and dead lobsters found no significant difference, either immediately after unpacking (independence level G = 0.386) or after a 24 hour recovery period in a seawater tank (independence level G = 0.0002).

Environmental Factors

The ambient temperature was not recorded for this experiment as only three loggers had been purchased at the time of experimentation. The control box (1000ml, 2 holes) had a temperature range of 10.75°C - 23.75°C, while the test boxes (500ml, 2 holes) had a temperature range of 9.25°C - 21.25°C and 12.25°C - 20.75°C (Figure 6.4.1a). The control box recorded higher temperatures when placed in the hot house than the test boxes.

The relative humidity logger in the control box recorded readings of 81% to 100% in the first 11 hours (Figure 6.4.1b). They then became erratic from contact with water (-400 to +400%). The test logger showed a relative humidity range of 77.75% - 100.25%. The recordings fluctuated proportionately to the temperature changes over the 30 hour experiment.

Pressure recorded in one of the test boxes showed pressure decreasing to 1031 mbar and increasing to 1044 mbar over the 30 hour simulation (Figure 6.4.1c). This occurred proportionately to the temperature variation the boxes were exposed to.

6.4.2 Discussion

Both treatment groups provided adequate relative humidity for the lobsters to carry out some gas exchange in air, and surprisingly, when placed in the hot house, the temperature was more extreme in the control box (1000ml ice bottle) than the replicated boxes which had a 500ml ice bottle. when placed in the hot house.

There was 100% survival and 93-98% health status of the lobsters in both treatments, immediately after unpacking and after a 24 hour recovery period. The proportion of strong lobsters was independent of the size of the ice bottle used, thus, there seemed to be no significant benefit in having a 1000ml ice bottle in preference to a 500ml ice bottle when 14-15 lobsters were packaged in a foam box with wood-shavings and 2 holes.

Figure 6.4.1a Temperatures inside the control box (1000ml ice bottle, 2 holes) and the replicated test boxes (500ml ice bottle, 2 holes), during the 30 hour simulation experiment.

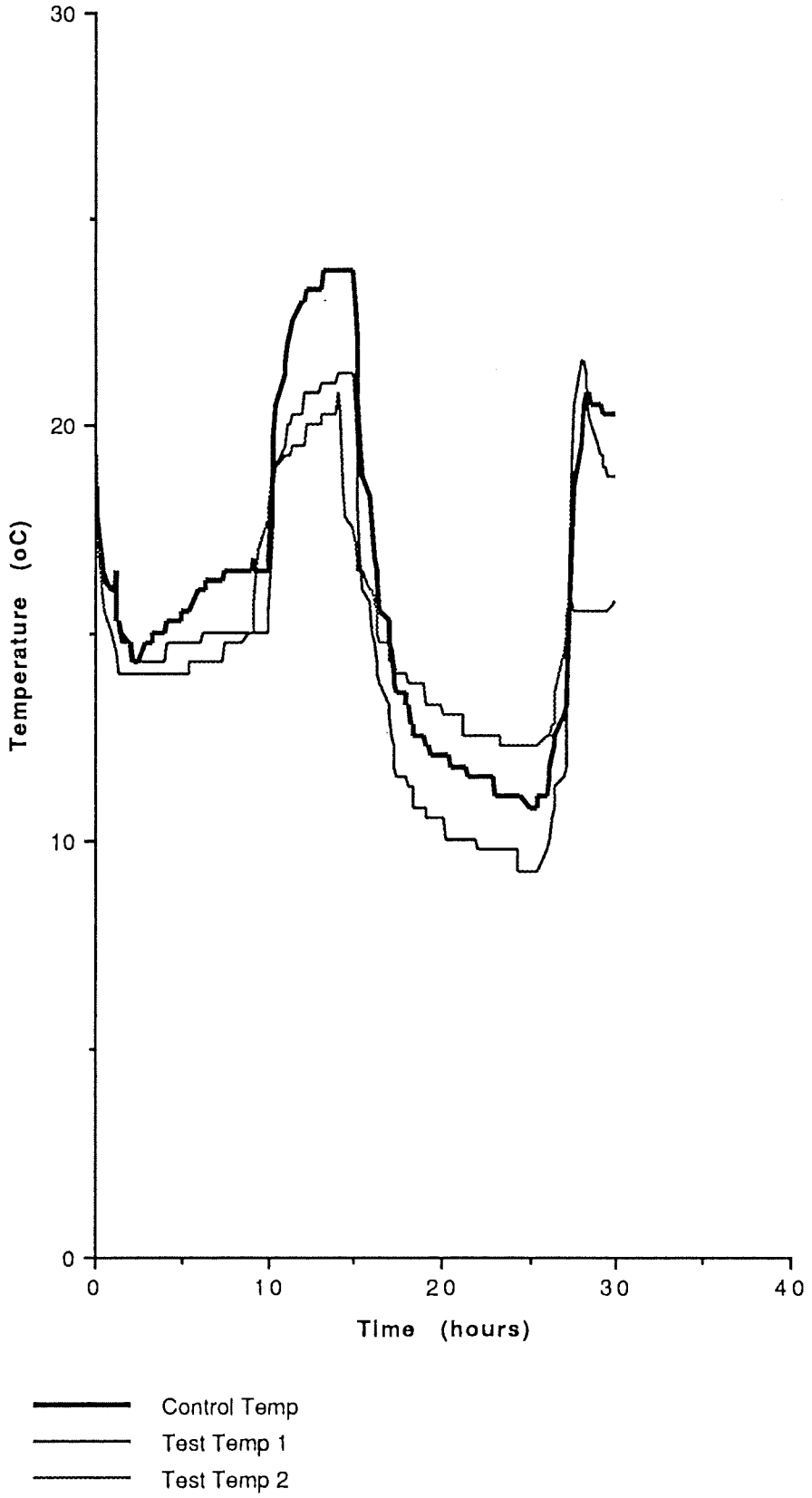


Figure 6.4.1b Relative humidity (%) recorded in one of the replicated test boxes (500ml ice bottle, No holes) during the 30 hour simulation experiment.

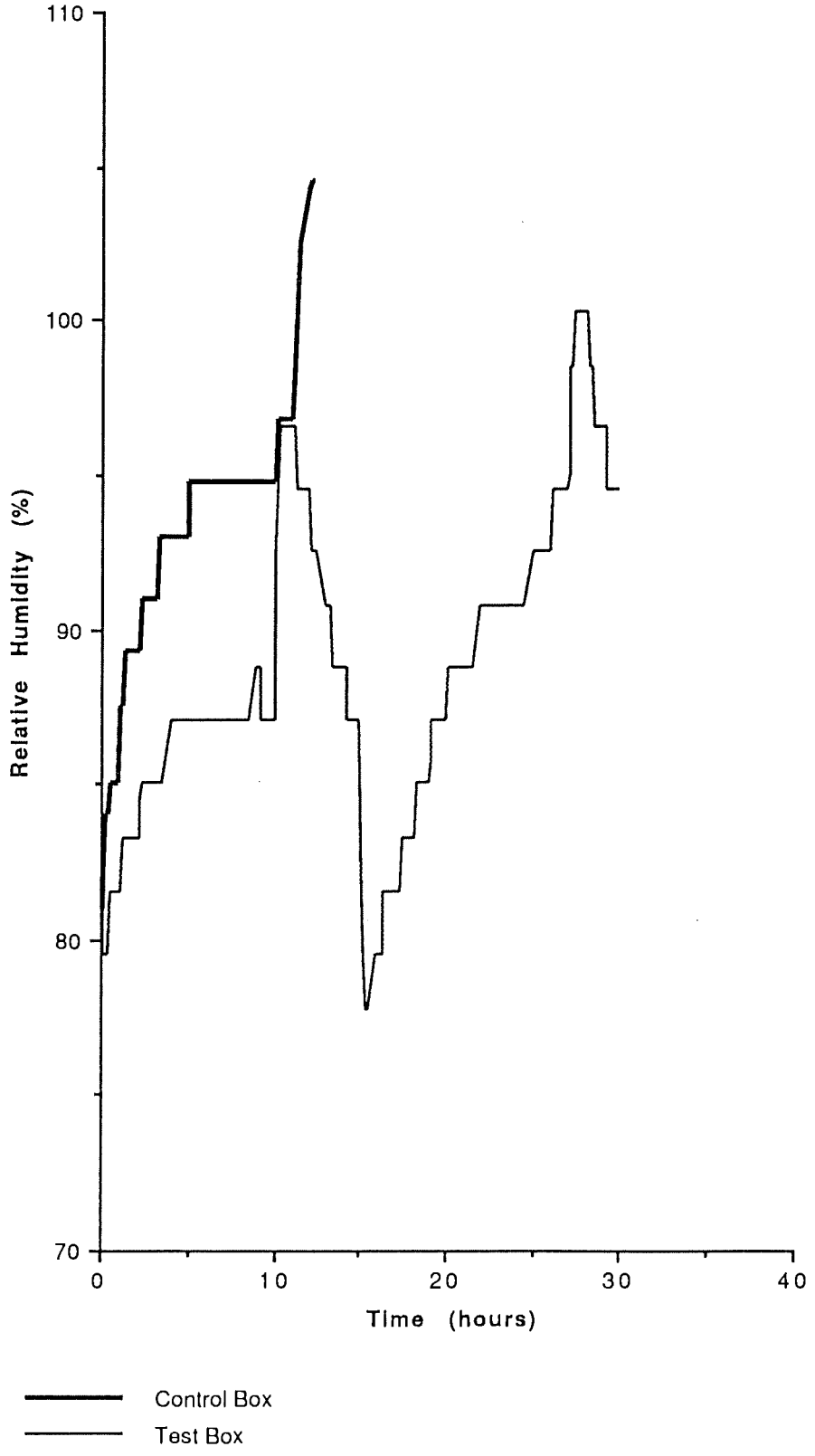
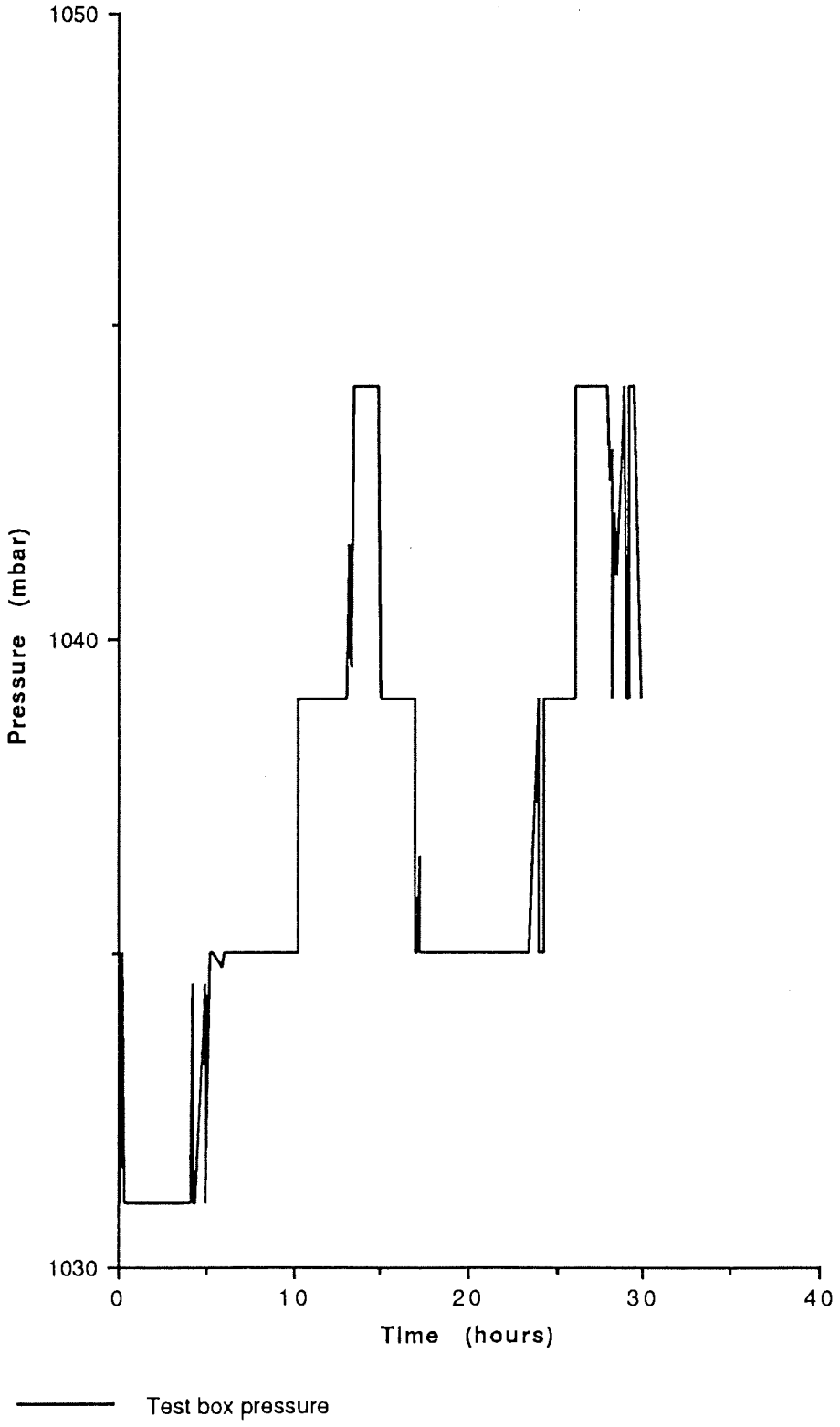


Figure 6.4.1c Pressure (mbar) recorded in one of the replicated test boxes (500ml ice bottle, 2 holes) during the 30 hour simulation experiment.



6.5 Experiment 3: Control (1000ml ice bottle, 2 holes) v's 500ml ice bottle, 2 holes

6.5.1 Results

Health Status

All lobsters had 100% survival in both treatment groups after the 30 hour simulation experiment (Table 6.5.1a). The control group had 100% health status as well, though the replicated test boxes had six weak animals (87% health status). After a 24 hour recovery period, a lobster from each treatment group had deteriorated in terms of health (Table 6.5.1b).

Table 6.5.1a Experiment Three: Health status of lobsters immediately after unpacking, from the control box (1000ml ice bottle, 2 holes) and from replicated test boxes (500ml ice bottle, 2 holes).

	Strong	Weak	Dead	Total	Strong %	Survival %
Replicate 1	14	1	0	15	93	100
Replicate 2	13	2	0	15	87	100
Replicate 3	12	3	0	15	80	100
Total	39	6	0	45	87	100
Control	15	0	0	15	100	100

Table 6.5.1b Experiment Three: Health status of lobsters after a 24 hour recovery period in a seawater tank, from the control box (1000ml ice bottle, 2 holes) and from replicated test boxes (500ml ice bottle, 2 holes).

	Strong	Weak	Dead	Total	Strong %	Survival %
Replicate 1	13	2	0	15	87	100
Replicate 2	14	1	0	15	93	100
Replicate 3	11	4	0	15	73	100
Total	38	7	0	45	84	100
Control	14	1	0	15	93	100

Statistical testing (G-test of independence with Yates correction of continuity, a 5% level) of the strong lobsters against weak and dead lobsters found no significant difference, either immediately after unpacking (independence level G = 1,206) or after a 24 hour recovery period in a seawater tank (independence level G = 0.203).

Environmental Factors

Temperature in the flow-through seawater system and in the chilled water bath at 0400 hours when packing occurred was 14.90°C and 10.50°C, respectively. The ambient temperature during the experiment ranged from 3.25°C to 31.75°C (Figure 6.5.1a). The control box (1000ml, 2 holes) had a temperature range of 7.50°C - 21.25°C, while the test boxes (500ml, 2 holes) had a temperature range of 7.50°C - 23.00°C and 6.50°C - 25.00°C (Figure 6.5.1a). The temperatures in the test boxes were highest during the first period in the hot house.

The relative humidity logger in the test box malfunctioned thus no data could be obtained. The logger in the control box showed a range between 77.75% and 116.25% (Figure 6.5.1b). The relative humidity changes were proportional to the ambient temperature variations.

Pressure recorded in one of the test boxes showed pressure decreasing to 1031 mbar and increasing to 1039 mbar (Figure 6.5.1c). The pressure changes occurred proportionately to the ambient temperature variation.

Table 6.5.1c The ice content and temperature of water within each ice bottle immediately after unpacking, in the control box (1000ml ice bottle, 2 holes), and the replicated test boxes (500ml ice bottle, 2 holes). (*The ice was very porous. Percentage determined by bulk, not liquid.)

Two holes	Ice Bottle °C	Ice Content %*
Replicate 1 (500ml)	5.7	None
Replicate 2 (500ml)	5.9	None
Replicate 3 (500ml)	6.6	None
Control (1000ml)	-1.8	3.0

The 500ml ice bottles in the replicate box were completely thawed, while the 1000ml ice bottle in the control box still contained approximately 3% ice in bulk after the 30 hour simulation (Table 6.5.1c)

6.5.2 Discussion

The presence of holes in both treatment groups allowed fluctuations in temperature to effect the ice bottles evenly. The test boxes had smaller sized ice bottles though, causing a faster melting rate and consequently, it decreased the ice bottles ability to keep the internal temperature stable. Thus, during the first period in the hot house the test boxes temperatures rose to 23.00 - 25.00°C, while the control box temperature only reached 21.25°C.

After the first placement of the boxes in the hot house the temperature in the replicated test boxes fluctuated more in proportion to the ambient temperature because the ice bottles had melted. This was noted after the 30 hour experiment finished where the test group ice bottles had no ice left and water temperatures between 5.70 - 6.60°C, while the control box ice bottle still had some ice and a -1.80 °C temperature.

Even with the test boxes being exposed to higher temperatures, there was 100% survival of the lobsters in both treatments, immediately after unpacking and after a 24 hour recovery period. The health status of the lobsters was quite different between treatments, with the health status of the control box decreasing from 100% to 93% and the health status in the replicated test boxes decreasing from an average of 87% to 84% in the recovery period.

There appeared to be no significant benefit in having a 1000ml ice bottle rather than a 500ml ice bottle, as the proportion of strong lobsters was found to be independent of the size of the ice bottle used (when packing 15 lobsters in a foam box with wood-shavings and 2 holes in the box). The health status in the test boxes (87% and 84%) were not acceptable on an industry basis though, while the control box health status was acceptable on unpacking (100%), and borderline after a 24 hour recovery period (93%). Thus, the study is inconclusive as to whether a 500ml ice bottle is sufficient to enhance survival.

Figure 6.5.1a Ambient temperature and temperatures inside the control box (1000ml ice bottle, 2 holes) and replicated test boxes (500ml ice bottle, 2 holes), during the 30 hour simulation experiment.

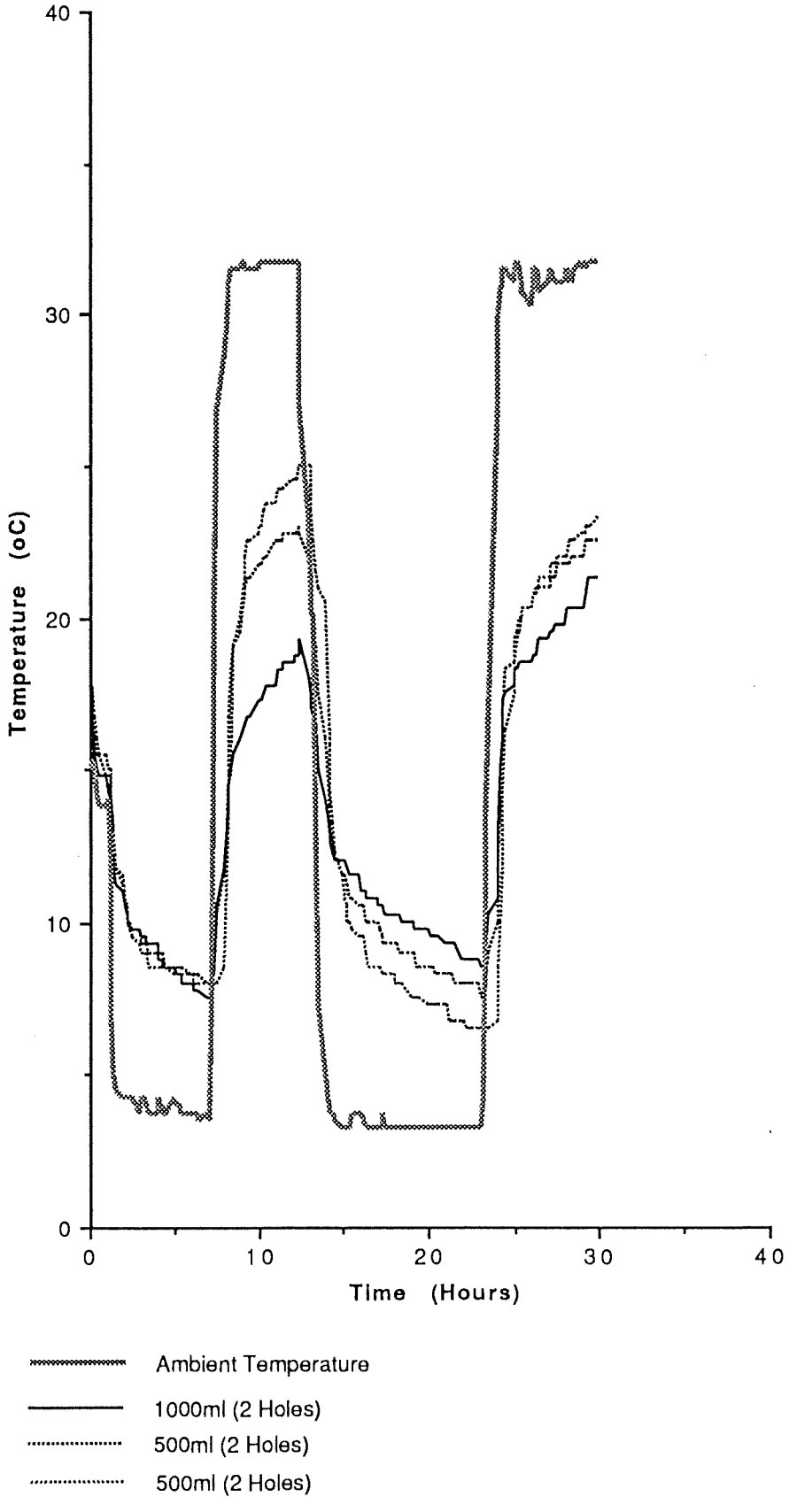


Figure 6.5.1b Relative humidity (%) recorded in one of the replicated test boxes (500ml ice bottle, No holes) during the simulation experiment.

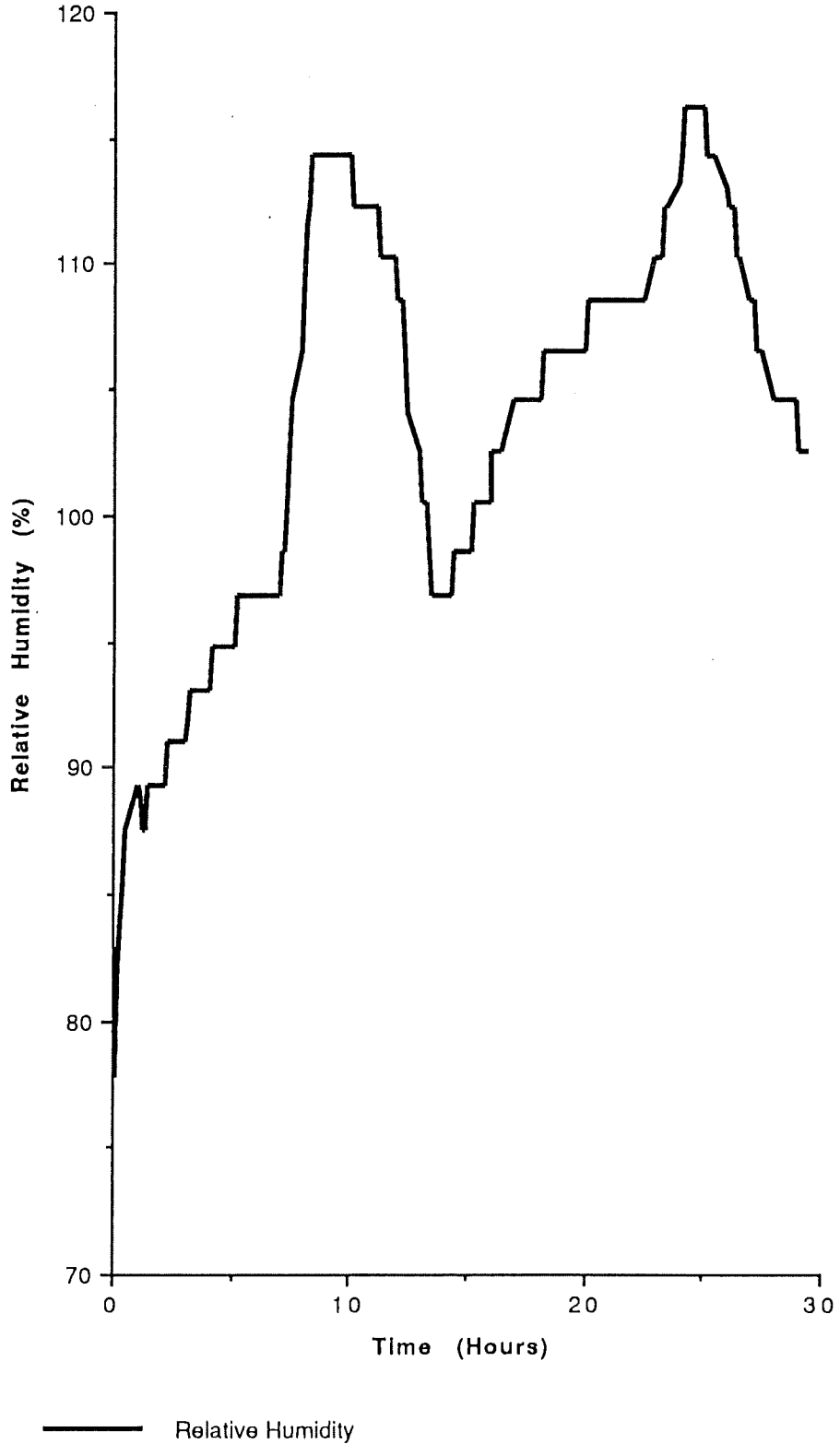
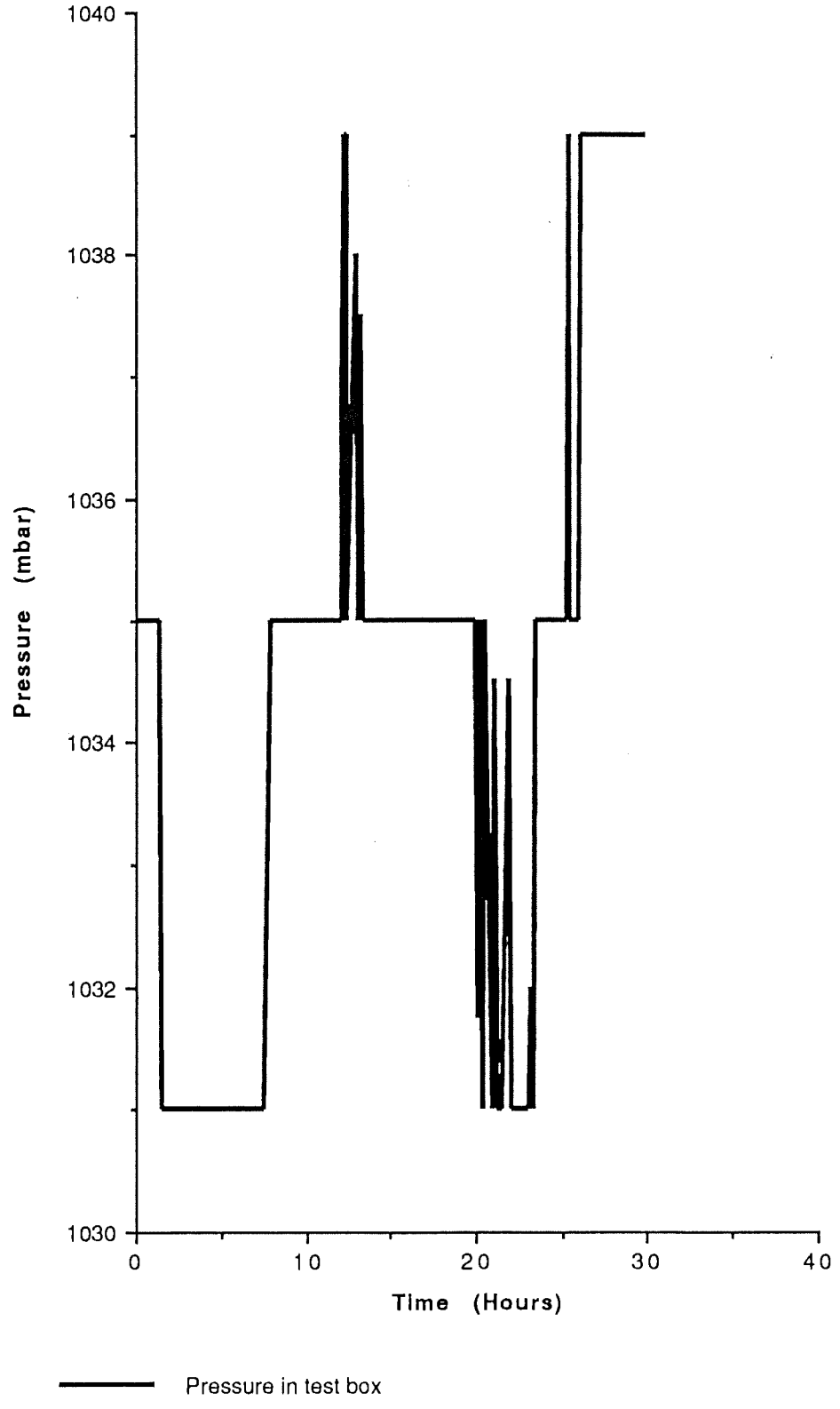


Figure 6.5.1c Pressure (mbar) recorded in one of the replicated test boxes (500ml ice bottle, 2 holes) during the 30 hour simulation experiment.



6.6 Experiment 4: Control (1000ml ice bottle, 2 holes) v's 500ml ice bottle, No holes.

6.6.1 Results

Health Status

All lobsters in the control box survived the 30 hour simulation experiment and the recovery period in seawater tanks with 100% health status. The lobsters from the replicated test boxes did not perform very well with an average of 92% survival and 63% health status immediately after unpacking (Table 6.6.1a). The majority of the weak animals recovered after the 24 hours in a seawater tank (ave: 81%), though three more lobsters died causing the average survival in the test boxes to fall to 85% (Table 6.6.1b).

Table 6.6.1a Health status of lobsters immediately after unpacking from the control box (1000ml ice bottle, 2 holes) and from the replicated test boxes (1000ml ice bottle, No holes).

	Strong	Weak	Dead	Total	Strong %	Survival %
Test 1	13	2	0	15	87	100
Test 2	8	6	1	15	53	93
Test 3	8	5	3	16	50	81
Total	29	13	4	46	63	92
Control	14	0	0	14	100	100

Table 6.6.1b Health status of lobsters after a 24 hour recovery period in seawater tanks, from the control box (1000ml ice bottle, 2 holes) and from the replicated test boxes (1000ml ice bottle, No holes).

	Strong	Weak	Dead	Total	Strong %	Survival %
Test 1	15	0	0	15	100	100
Test 2	11	2	2	15	73	87
Test 3	11	0	5	16	69	69
Total	37	2	7	46	81	85
Control	14	0	0	14	100	100

Statistical testing (G-test of independence with Yates correction of continuity, at 5% level) of the strong lobsters against weak and dead lobsters found that there was a significant difference immediately after unpacking (independence level G = 7.170). After the 24 hours recovery period there was no significant difference (independence level G = 2.383).

Environmental Factors

The temperature in the recirculating seawater system and the chilled water bath at 0330 hours when packing occurred was 16.1°C and 10.0°C. The ambient temperature during the experiment ranged from 2.25°C - 32.25°C (Figure 6.6.1a). The control box (1000ml, 2 holes) had a temperature range of 8.50°C - 21.25°C, while the test boxes (500ml, No holes) showed a temperature range of 4.50 - 26.25°C and 6.50°C - 25.25°C (Figure 6.6.1a)

The relative humidity logger in the control box malfunctioned, thus, no results could be obtained. The logger in the test box showed a range between 85% and 92.50% over the first 20 hours before the logger came in contact with water giving erratic readings (Figure 6.6.1b). There seemed to be an inversely proportionate relationship between the pressure and temperature over those first 20 hours.

The pressure recordings in one of the test boxes showed pressure decreasing to 1031 mbar and increasing to 1039 mbar within the closed system (foam box with no holes) (Figure 6.6.1c). A proportionate relationship with the fluctuating ambient temperature was observed.

Table 6.6.1c The ice content and temperature of water within each ice bottle immediately after unpacking, in the control box and the replicated test boxes (*The ice was very porous, % determined by bulk, not liquid).

	Ice Bottle °C	Ice Content %
Replicate 1 (500ml, No holes)	5.3	None
Replicate 2 (500ml, No holes)	2.9	None
Replicate 3 (500ml, No holes)	7.2	None
Control (1000ml, 2 holes)	-2.7	30.0

The test box ice bottle (500ml) had completely thawed out while the control box ice bottle (1000ml) was still had 30% ice left in bulk (very porous).

6.6.2 Discussion

The proportion of strong lobsters was found to be dependent on the combination of either a 1000ml ice bottle and 2 holes punched into a foam box, or a 500ml ice bottle and no holes punched into a foam box, immediately after the lobsters were unpacked. After a 24 hour recovery period though, the health status of the lobsters improved enough, that with statistical testing, there was no significant difference between the two treatment groups.

After a 24 hour recovery period, the strength of the lobsters improved significantly. Independence was calculated for the strength of the lobsters in each treatment against the size of the ice bottle used and the presence of holes. This occurred even with an average survival and health status of 85% and 81% respectively in the test box, compared with 100% survival and health status in the control boxes.

The ice bottles in the test boxes were completed thawed and providing little benefit to the package at the end of the 30 hour simulation. The ice bottle in the control box still had some ice remaining with a temperature of -2.7oC. Thus, the ice bottle was still absorbing heat from the package and helping to stabilize the temperature in the box.

The relative humidity recorded inside a box from each treatment showed adequate moisture being available for the lobsters to carry out some gas exchange. Relative humidity was not a determining stress factor in the difference of health status, though the high temperatures recorded in the test boxes was definitely causing the animals stress. This was seen with the improvement in health status of weak lobsters over the 24 hour recovery period. When unpacking, there were only 29 strong lobsters from 46 lobsters in the test boxes. After the recovery period, 8 lobsters had regained health status.

The survival figures were below the accepted industry level (95%+), and with a significant difference found in the health status of the lobsters immediately after unpacking, it is recommended that 15 - 16 lobsters are not packed in a foam box with wood-shavings, a 500ml ice bottle and no holes punched in the box.

Figure 6.6.1a Ambient temperature and temperatures inside the control box (1000ml ice bottle, 2 holes) and replicated test boxes (500ml ice bottle, No holes), during the 30 hour simulation experiment.

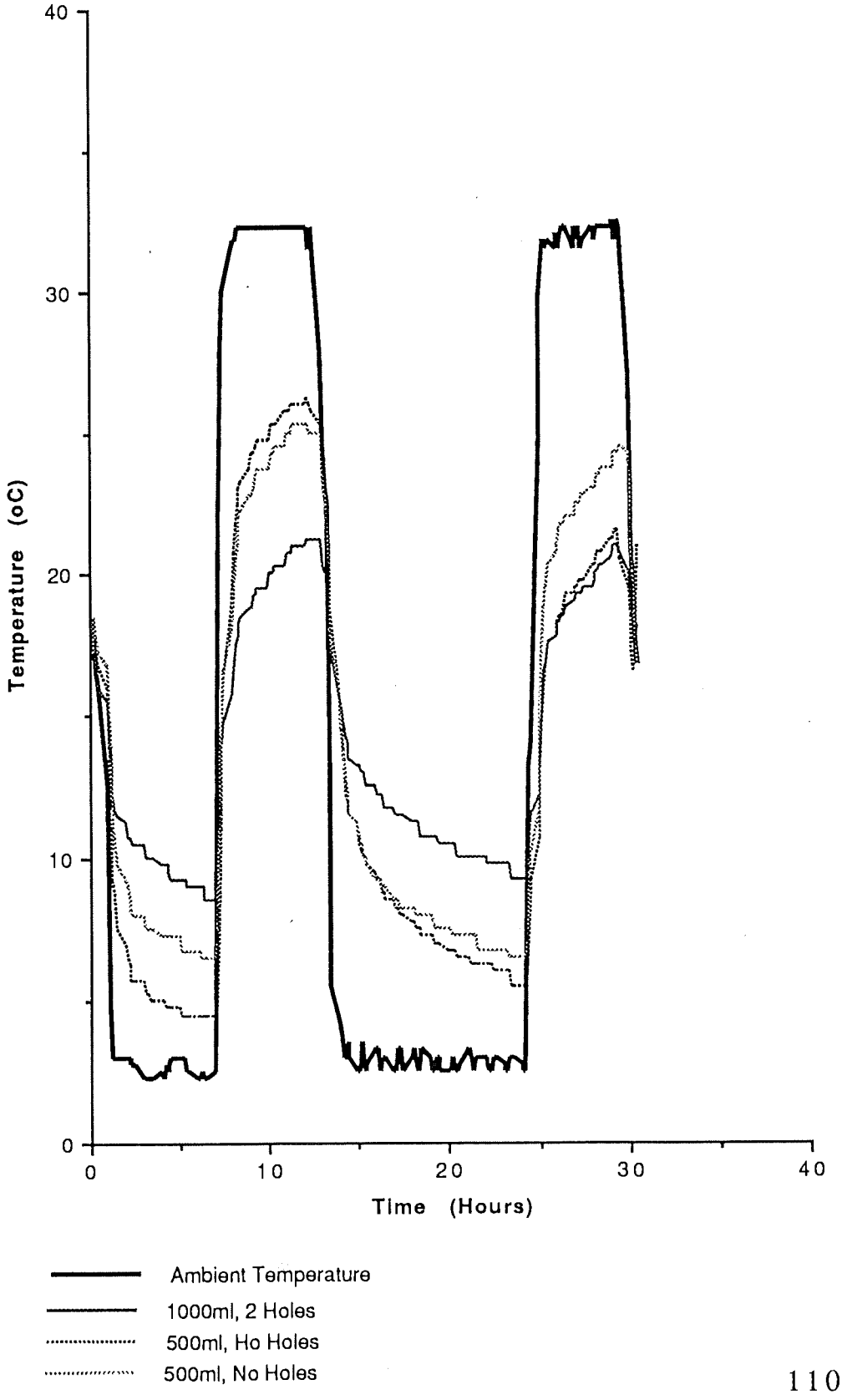


Figure 6.6.1b Relative humidity (%) recorded in one of the replicated test boxes (500ml ice bottle, No holes) during the 30 hour simulation experiment.

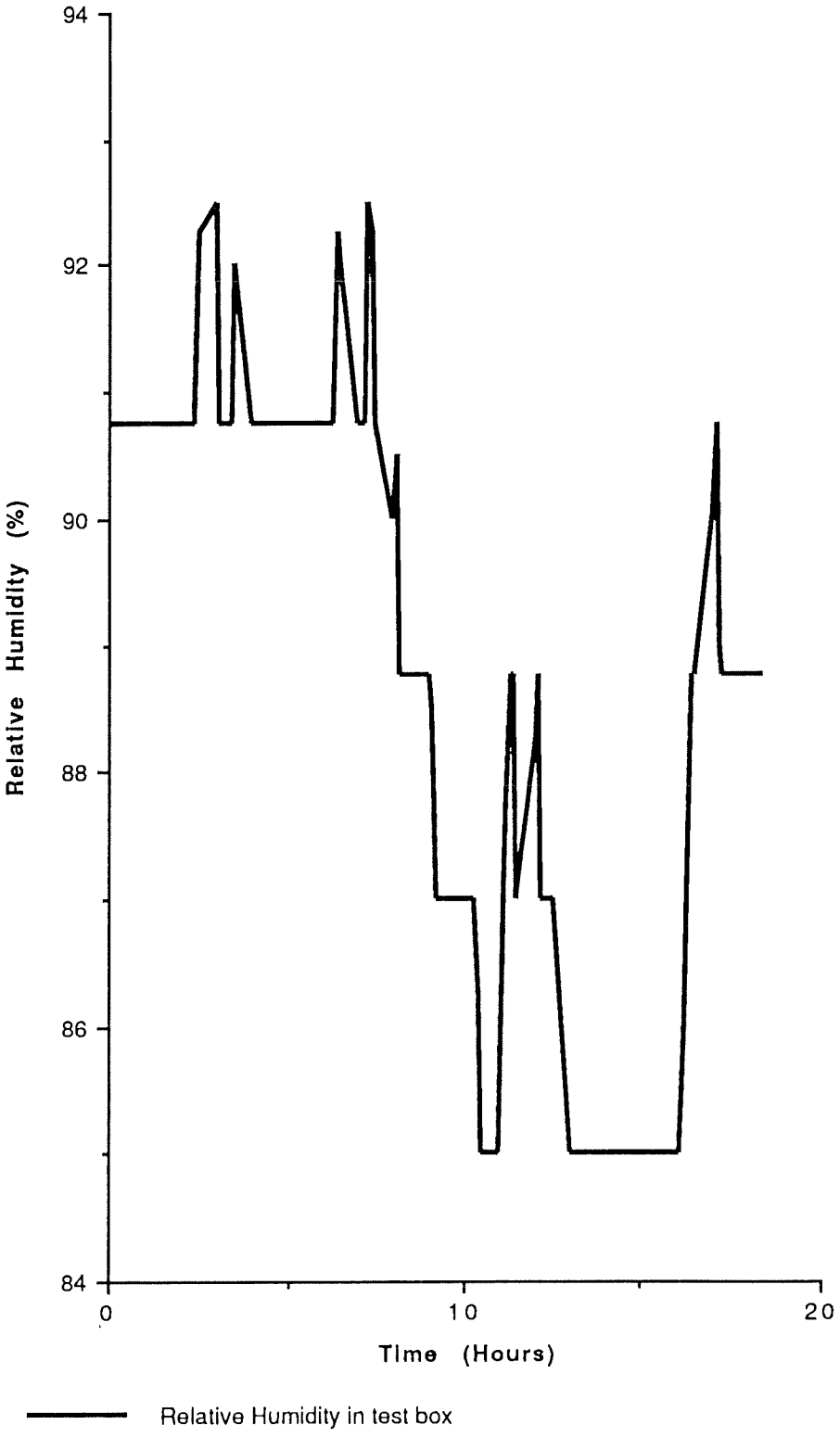


Figure 6.6.1c Pressure (mbar) recorded in one of the replicated test boxes (500ml ice bottle, No holes) during the 30 hour simulation experiment.

6.7 Experiment 5: Control (1000ml ice bottle, 2 holes) v's 500ml ice bottle, No holes

6.7.1 Results

Health Status

All lobsters in the control box survived the 30 hour simulation with 93% health status. In the replicated test boxes, survival was 93% though health status was very low (65%) with 12 weak animals (Table 6.7.1a). After a 24 hour recovery period in a seawater tank, survival had decreased in both treatments (Table 6.7.1b).

Table 6.7.1a Health status of lobsters immediately after unpacking from the control box (1000ml ice bottle, 2 holes) and from the replicated test boxes (1000ml ice bottle, No holes).

	Strong	Weak	Dead	Total	Strong %	Survival %
Replicate 1	8	5	1	14	57	93
Replicate 2	10	5	0	15	67	100
Replicate 3	10	2	2	14	71	86
Total	28	12	3	43	65	93
Control	13	1	0	14	93	100

Table 6.7.1b Health status of lobsters after a 24 hour recovery period in seawater tanks, from the control box (1000ml ice bottle, 2 holes) and from the replicated test boxes (1000ml ice bottle, No holes).

	Strong	Weak	Dead	Total	Strong %	Survival %
Replicate 1	8	4	2	14	57	86
Replicate 2	10	3	2	15	67	87
Replicate 3	11	1	2	14	79	86
Total	29	8	6	43	67	86
Control	12	1	1	14	86	93

Statistical testing (G-test of independence with Yates correction of continuity, at 5% level) of the strong lobsters against weak and dead lobsters found no significant difference, either immediately after unpacking (independence level G = 1.585), or after a 24 hour recovery period in a seawater tank (independence level G = 1.022).

Environmental Factors

The ambient temperature during the experiment was unable to be recorded as only three temperature recorders had been purchased at the time of experimentation. The control box (1000ml, 2 holes) had a temperature range of 8.25°C - 18.50°C, while the test boxes (500ml, no holes) showed a temperature range of 6.00°C - 23.50°C and 9.00°C - 23.50°C. Thus, the absence of holes and the use of a 500ml ice bottle allowed the temperature inside the replicated test boxes to peak higher than the temperature inside the control box (Figure 6.7.1a).

The relative humidity recorded in the control box started at 96.75% and rose to over 100% in one hour (Figure 6.7.1b). The recordings then became erratic which was likely to have been a result from the logger coming in contact with water (-400 to +400%). The test logger showed a gradual rise over the 30 hours from 79.50% - 102.25%, with a slight proportional relationship to temperature.

The pressure recorded in one of the test boxes showed pressure decreasing to 1017 mbars and increasing to 1035 mbars within the closed system (foam box with no holes) (Figure 6.7.1c). The ambient temperature changes seemed to influence the pressure readings inside the box proportionately over the 30 hour period.

No recordings were made on the ice content and temperature of the ice bottles.

6.7.2 Discussion

Statistical testing suggested that there was no significant benefit in having a 1000ml ice bottle and 2 holes rather than a 500ml ice bottle when packing 14 - 15 lobsters in a foam box with wood-shavings. This means that the proportion of strong lobsters was independent of the size of the ice bottle used and the presence of holes in the foam box.

The relative humidity within the treatment groups provided adequate moisture for the lobsters to carry out some gas exchange. Thus, part of the reason for the weakness of the lobsters in the test boxes was from stress related to the high temperatures recorded inside the test boxes through the combination of using of a 500ml ice bottle in a foam box with no holes.

The percentage of survival (93% and 86%) and health status (65% and 67%) of the lobsters in the test boxes was not acceptable on an industry basis, either immediately after unpacking or after a 24 hour recovery period, respectively. The health status of the control box lobsters was not very good immediately after unpacking or after the 24 hour recovery period either (93% and 86%).

Without sufficient replication for conclusive statistical testing though, it was hard to determine whether the lower than usual health status in the control group was just because of natural variation. The overall outcome suggests that other environmental or physiological factors not observed during the experiment may have played an equal role in lowering the health status of both treatment groups. Thus, this study was inconclusive. Further research is required to determine whether the combination of 2 holes punched into the foam box and a 1000ml ice bottle are necessary when packing lobsters with wood-shavings, or whether the system could be modified to not punching any holes in the box and reducing the ice bottle size to 500ml.

Figure 6.7.1a Temperatures recorded inside the control box (1000ml ice bottle, 2 holes) and inside the replicated test boxes (500ml ice bottle, No holes), during the 30 hour simulation experiment.

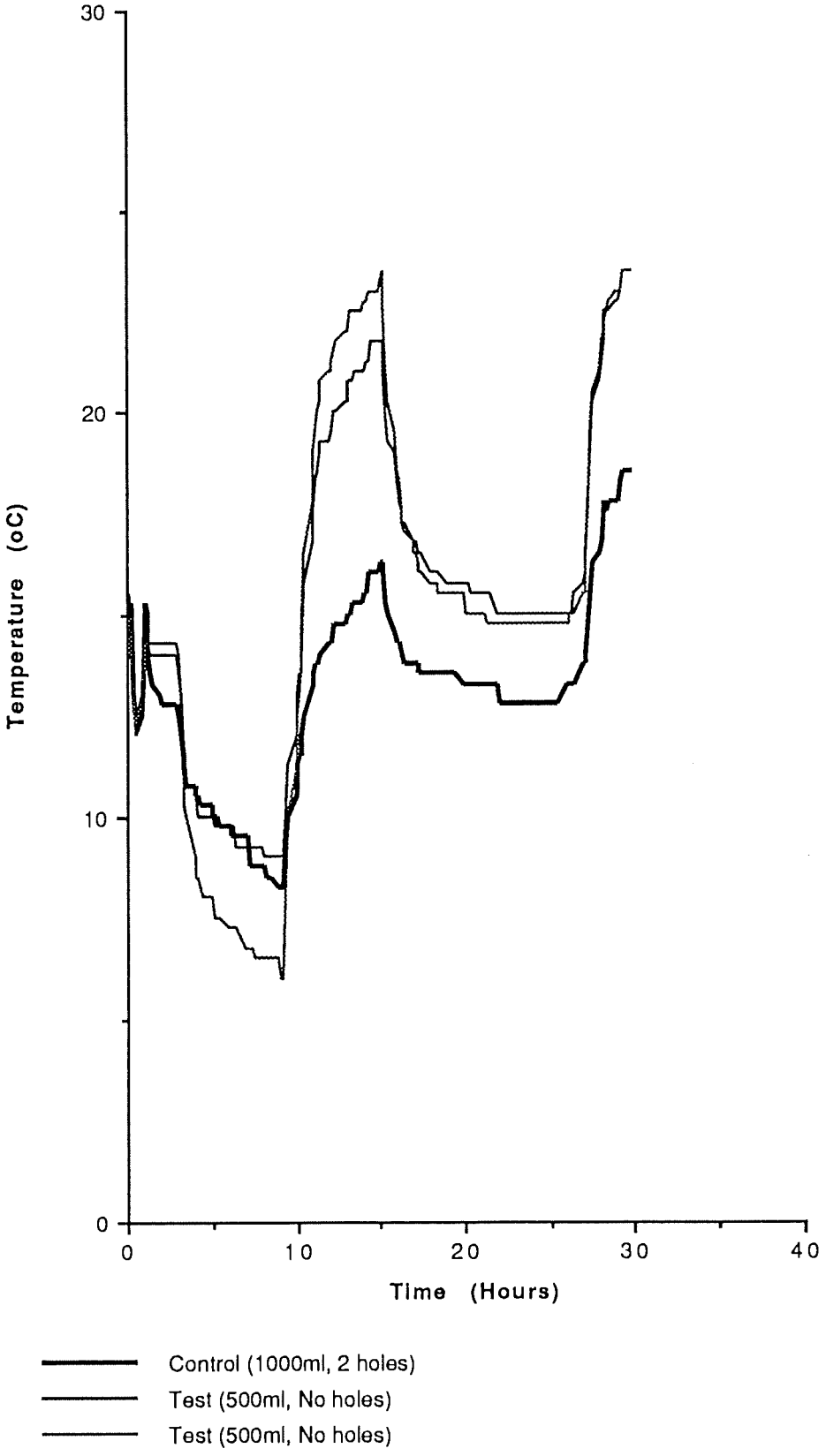


Figure 6.7.1b Relative humidity (%) recorded in the control box (1000ml ice bottle, 2 holes) and one of the replicated test boxes (500ml ice bottle, No holes), during the 30 hour simulation experiment.

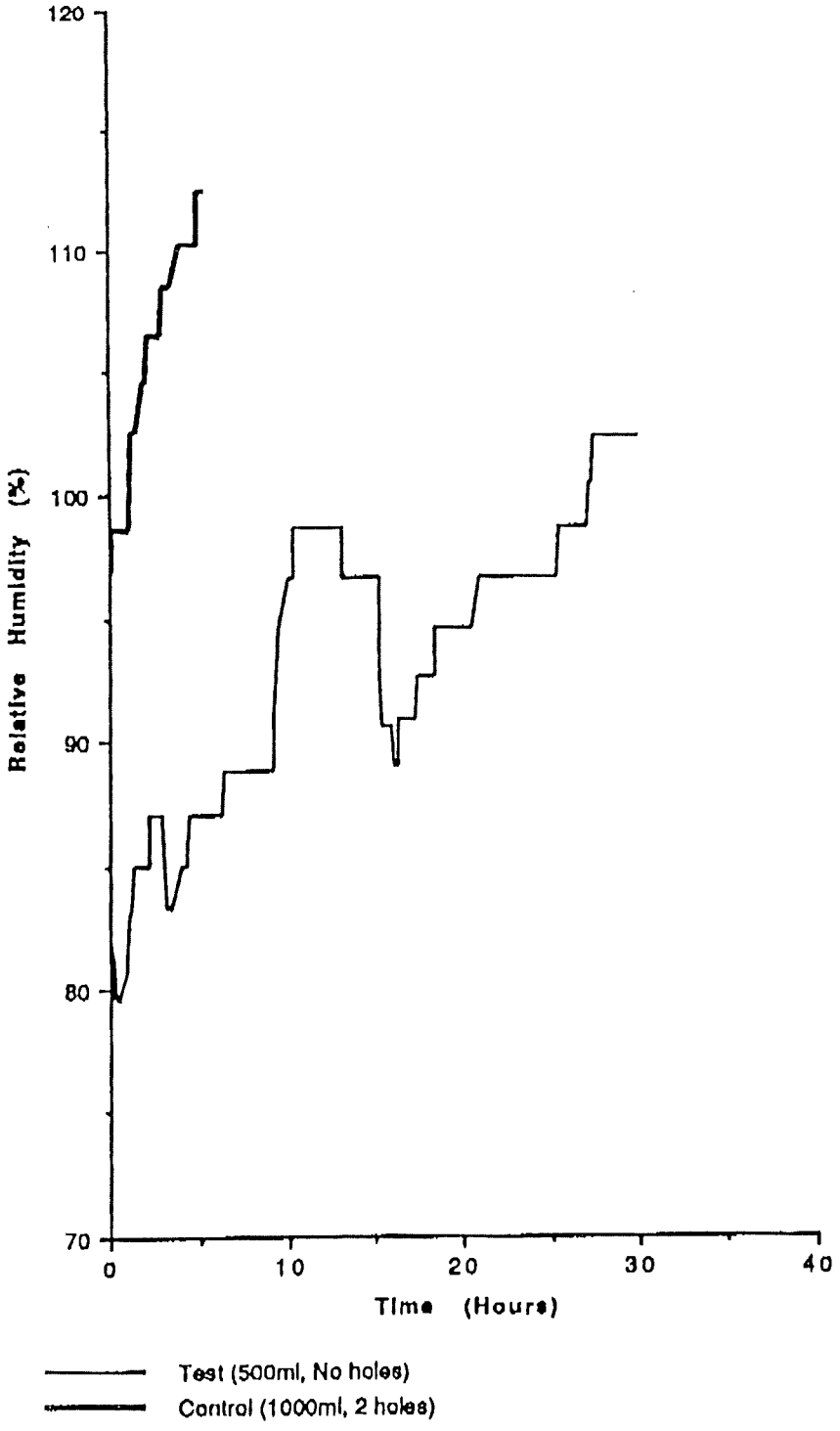
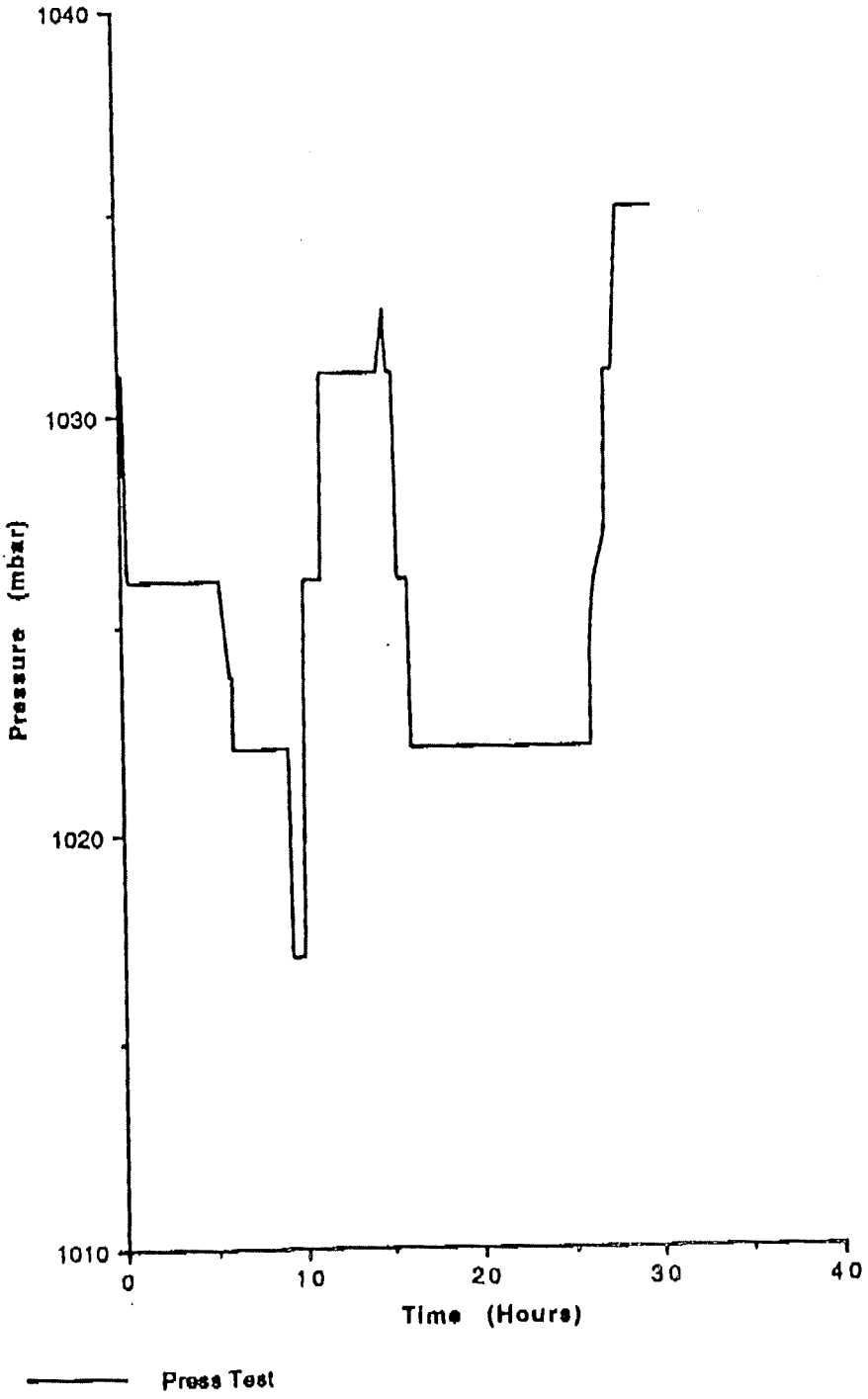


Figure 6.7.1c Pressure (mbar) recorded in one of the replicated test boxes (500ml ice bottle, no holes) during the 30 hour simulation experiment.



6.8 Summary and Recommendations

Statistical testing found that only experiment 4 showed the health status of the lobsters being dependent on the way they were packed (control of 1000ml ice bottle and 2 holes v's 500ml ice bottle and no holes) (Table 6.8). This was immediately after unpacking, and independence was returned after a 24 hour recovery period in which several lobsters health status was regained.

Table 6.8 Summary of results from 5 individual simulation experiments. In each experiment the packing style (T) was compared with a control (C) (1000ml ice bottle and 2 holes punched into either end of the foam box).

Packing style	Statistical Testing		Industry Acceptance					
			Survival				Health Status	
	UN	24	Unpack		24 hour		Unpack	24 hour
			C	T	C	T	C T	C T
1000ml, No holes	x	x	@	•	@	•	@ •	• •
500ml, Two holes	x	x	@	@	@	@	• •	• •
500ml, Two holes	x	x	@	@	@	@	@ •	• •
500ml, No holes	**	x	@	•	@	•	@ •	@ •
500ml, No holes	x	x	@	•	•	•	• •	• •

x - No significant difference (health status independent of packing style)

** - Significant difference (health status dependent of packing style)

@ - 95% or higher survival or health status accepted by industry

• - Less than 95% survival or health status.

The relative humidity was found not to be a dominant stress factor, with relative humidity over 70% being recorded throughout the simulation experiments in boxes with holes and without holes.

Pressure did not vary much within the boxes but was noted as fluctuating proportionally to the ambient temperature when the boxes were transferred from one location to the other (eg, refrigerator to hot house).

Temperature stress to the lobsters was noted, especially in the test boxes from experiments 4 and 5. Several weak lobsters regained health status once placed into seawater tanks for a 24 hour recovery period. The temperature within those test boxes reached 25.00°C.

Looking at the survival of the lobsters in terms of industry acceptance, the control boxes provided the best results. Experiments 2 and 3, comparing the control (1000ml ice bottle, 2 holes) against a 500ml ice bottle and 2 holes, had acceptable survival rates as well, though the health status of the animals was not quite as good as the control box.

Taking into account the extreme temperature conditions the lobsters were exposed to during the 30 hour simulation experiment, and the lack of replication used in this pilot study, a foam box packed with wood-shavings, a 500ml ice bottle and 2 holes punched into either end are an acceptable alternative to the current packaging systems used in the western rock lobster industry.

The results were inconclusive as to whether lobsters can be packed in foam boxes using a 1000ml ice bottle and no holes. Results did show however, that a combination of no holes and a 500ml ice bottle is detrimental to the health of the lobsters.

Recommendation

Since freight is a very expensive component of the post-harvest handling costs in the western rock lobster industry, it is possible for processors to decrease the size of the ice bottle currently used (1000ml). Under common climatic conditions (<33.00°C as in experiment) the size of the ice bottle could be reduced to a 500ml ice bottle. A good knowledge of the ambient temperature at the overseas destination will help to determine what size ice bottle is required, taking into account the results of experiments two and three and the ambient temperatures the boxes were exposed to.

The live export of western rock lobsters in the 1993/94 season was 2,272,632 kilograms. If the lobsters had been all exported in 10kg net boxes, and packed with 500ml ice bottles rather than 1000ml ice bottles, a saving of approximately $681,789.60 could have been made (500ml water/ice = approximately $3.00/box freight).

6.9 Experiment 6: Control (500ml, 4 holes, Wood-shavings) v's 500ml, no holes, Hessian.

6.9.1 Results

Health Status

All lobsters in the control box survived, with 94% health status immediately after unpacking (Table 6.9.1a), and 100% health status after a 24 hour recovery period (Table 6.9.1b). The survival and health status of the lobsters in the replicated test boxes was very poor. Survival averaged 87% immediately after unpacking, with an average health status of 35%. During the recovery period two more lobsters died (ave: 83%), and 18 lobsters regained health status (ave: 74%).

Table 6.9.1a Health status of lobsters immediately after unpacking, from the control box (500ml, 4 holes, wood-shavings) and replicated test boxes (500ml, no holes, hessian).

	Strong	Weak	Dead	Total	Strong %	Survival %
Test 1	9	6	0	15	60	100
Test 2	3	10	2	15	20	87
Test 3	4	8	4	16	25	75
Total	16	24	6	46	35	87
Control	15	1	0	16	94	100

Table 6.9.1b Health status of lobsters after a 24 hour recovery period in a seawater tank, from the control box (500ml, 4 holes, wood-shavings) and replicated test boxes (500ml, no holes, hessian).

	Strong	Weak	Dead	Total	Strong %	Survival %
Test 1	12	2	1	15	80	93
Test 2	11	1	3	15	73	80
Test 3	11	1	4	16	69	75
Total	34	4	8	46	74	83
Control	16	0	0	16	100	100

Statistical testing (G-test of independence with Yates correction of continuity, at 5% level) of the strong lobsters against weak and dead lobsters found that there was a significant difference immediately after unpacking (independence level G = 15.949) and after a 24 hour recovery period in a seawater tank (independence level G = 4.740).

Environmental Factors

The ambient temperature was unable to be recorded during the simulation experiment as only three temperature recorders had been purchased at the time. The control box (500ml, 4 holes, wood-shavings) had a temperature range of 6.50°C - 25.75°C (Fig. 6.9.1a), while the test boxes (500ml, no holes, hessian) had a temperature range of 8.50°C - 22.00°C (Fig. 6.9.1b) and 6.25°C - 21.00°C (Fig. 6.9.1c). Thus, the control box with 4 holes had higher temperatures than the test boxes with no holes punched in them.

The relative humidity recorded in the control box showed a relative humidity of 98% when packing and became erratic immediately after from contact with water (-55% to +415%). The recorder in one of the test boxes malfunctioned, thus, no results could be obtained.

The pressure recorded in one of the test boxes showed pressure decreasing to 14.76 psia and increasing to 15.03 psia within the closed system (Fig. 6.9.1.d). The temperature changes the boxes were exposed to influenced the pressure readings inside the box proportionately over the 30 hour period.

6.9.2 Discussion

Statistical testing suggested that there was a significant difference in the health status of 15-16 lobsters when the two treatments were compared. The use of wood-shavings and 4 holes punched into the box was significantly better than using hessian with no holes punched into the box, both immediately after unpacking and after a 24 hour recovery period in a seawater tank. This occurred even with higher temperatures being recorded in the control box from the presence of holes.

The presence of holes may have allowed for some gas exchange to occur in the control box, thus, playing an important role in the control box lobsters higher survival and health status.

Another reason for lower survival and health status in the test boxes was probably the lack of support the hessian gave the lobsters. The positioning of the lobsters in the boxes was not studied to determine where the weak and dead lobsters were placed. Since the hessian was just weaved through the lobsters as packed, the animals in the bottom of the box may have weakened from stress related with being squashed.

On an industry basis, the survival in the control box was acceptable. The survival and health status in the test boxes was well below industry standards.

Figure 6.9.1a Temperature (^{0}C) recorded in the control box (wood-shavings, 4 holes, 500ml ice bottle) during the 30 hour simulation experiment.

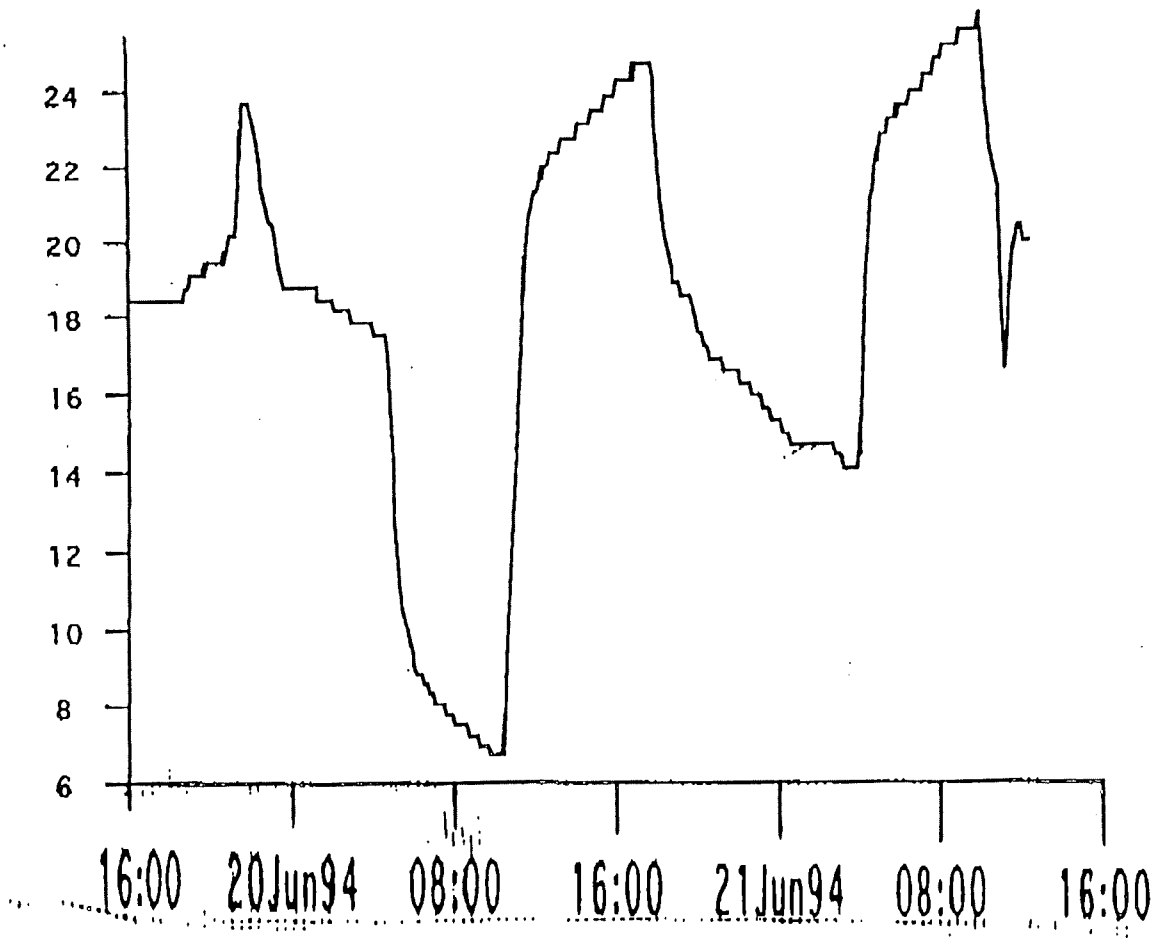


Figure 6.9.1b Temperature (°C) recorded in one of the test boxes (hessian packing material, no holes, 500ml ice bottle) during the 30 hour experiment.

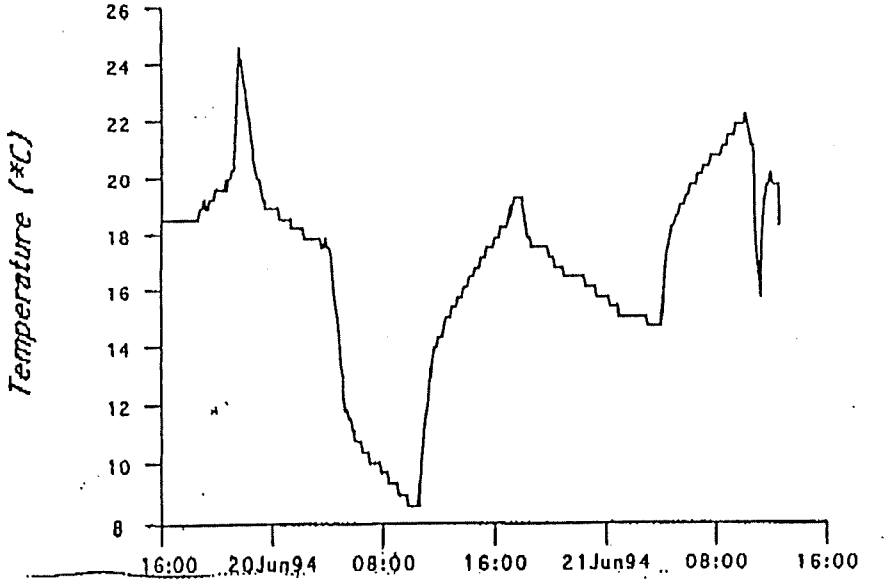


Figure 6.9.1c Temperature (°C) recorded in one of the test boxes (hessian packing material, no holes, 500ml ice bottle) during the 30 hour experiment.

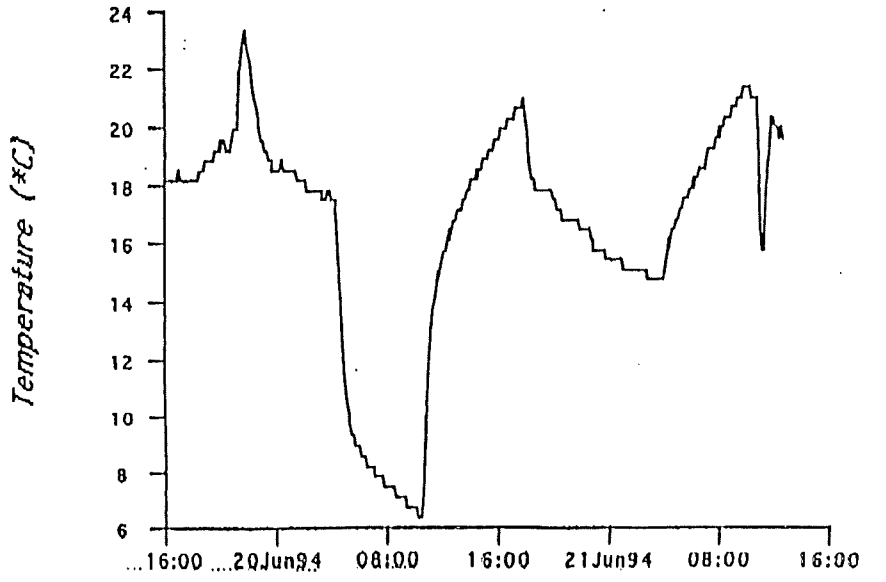
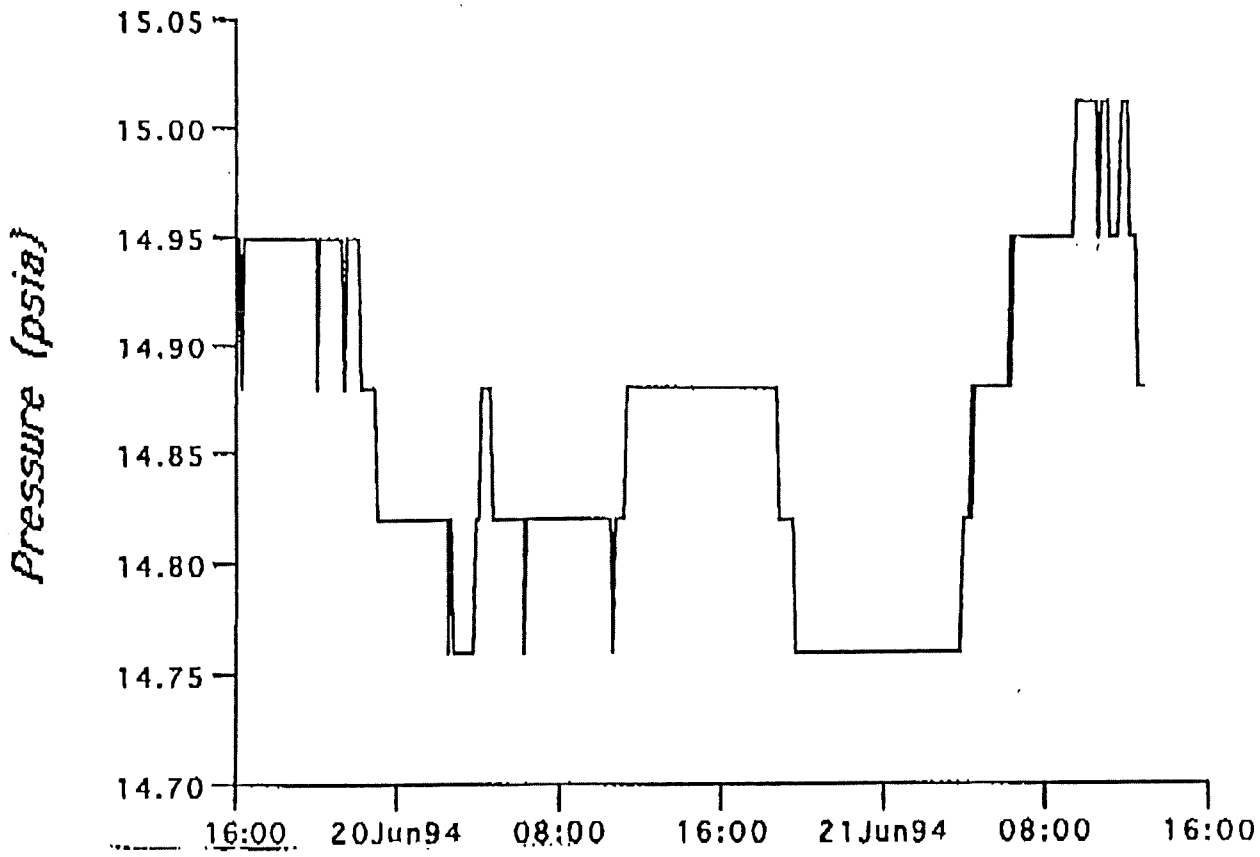


Figure 6.9.1d Pressure (Psia) recorded in one of the test boxes (hessian packing material, no holes, 500ml ice bottle) during the 30 hour simulation.



6.10 Experiment 7: Control (500ml, 4 holes, wood-shavings) v's 500ml, no holes, Foam.

6.10.1 Results

Health status

All lobsters in the control box survived and had a 100% and 93% health status immediately after unpacking (Table 6.10.1a) and after a 24 hour recovery period (Table 6.10.1b), respectively. The survival and health status of lobsters in the replicated test boxes was very poor. Survival averaged 86% immediately after unpacking, with an average health status of 34%. During the recovery period five more lobsters died (ave: 75%), and 11 lobsters regained health status (ave: 59%).

Table 6.10.1a Health status of lobsters immediately after unpacking, from the control box (500ml, 4 holes, wood-shavings) and from the replicated test boxes (500ml, no holes, foam).

	Strong	Weak	Dead	Total	Strong %	Survival %
Test 1	5	7	2	15	33	87
Test 2	5	1	2	14	36	85
Test 3	5	8	2	15	33	87
Total	15	23	6	44	34	86
Control	14	0	0	14	100	100

Table 6.10.1b Health status of lobsters after a 24 hour recovery period in a seawater tank, from the control box (500ml, 4 holes, wood-shavings) and from the replicated test boxes (500ml, no holes, foam).

	Strong	Weak	Dead	Total	Strong %	Survival %
Test 1	9	3	3	15	60	80
Test 2	8	2	4	14	57	71
Test 3	9	2	4	15	60	73
Total	26	7	11	44	59	75
Control	13	1	0	14	93	100

Statistical testing (G-test of independence with Yates correction of continuity, at 5% level) of the strong lobsters against weak and dead lobsters found that there was a significant difference immediately after unpacking (independence level G = 18.993) and after a 24 hour recovery period in a seawater tank (independence level G = 4.740).

Environmental Factors

The ambient temperature recorded during the experiment ranged from 2.25°C - 32.50°C (Fig. 6.10.1a) The control box (500ml, 4 holes, wood-shavings) had a temperature range of 8.00°C - 27.75°C (Fig. 6.10.1b), while the test boxes (500ml, no holes, foam) had temperatures ranging from 6.00°C - 26.75°C (Fig. 6.10.1c) and 6.00°C - 24.00°C (Fig. 6.10.1d).

The relative humidity recorded in the control box ranged from 91% to 93% for the first 9 hours, then malfunctioned. In one of the test boxes, the relative humidity ranged from 83% to 116% over the 30 hours (Fig. 6.10.1e).

The pressure recorded in one of the test boxes showed pressure decreasing to 14.87 psia and increasing to 15.14 psia within the closed system (Fig 6.10.1f). The changes in pressure were proportional to the ambient temperatures.

6.10.2 Discussion

Statistical testing found that there was a significant difference in the health status of 14 - 15 lobsters when packed using the two treatments. The use of wood-shavings as the packing material with 4 holes punched into the box, was significantly better than using foam with no holes punched into the boxes, both immediately after unpacking and after a 24 hour recovery period in a seawater tank. This occurred even with higher temperatures being recorded in the control box.

The presence of holes in the control box may have allowed for some gas exchange to occur. In both treatments there was adequate relative humidity for some gas exchange to be carried out by the lobsters, whether a closed or open system. Thus, the use of foam as the packing material in the test boxes must have been a determining factor of the lobsters health status. The foam sheets could not be packed tightly around the lobsters and used to fill in gaps, thus, did not provide the same amount of support to the

lobsters as the wood-shavings. This created stressful conditions for the lobsters, causing their health status to be well below the health status required on an industry basis.

Figure 6.10.1a Ambient temperature (°C) recorded during the 30 hour simulation experiment.

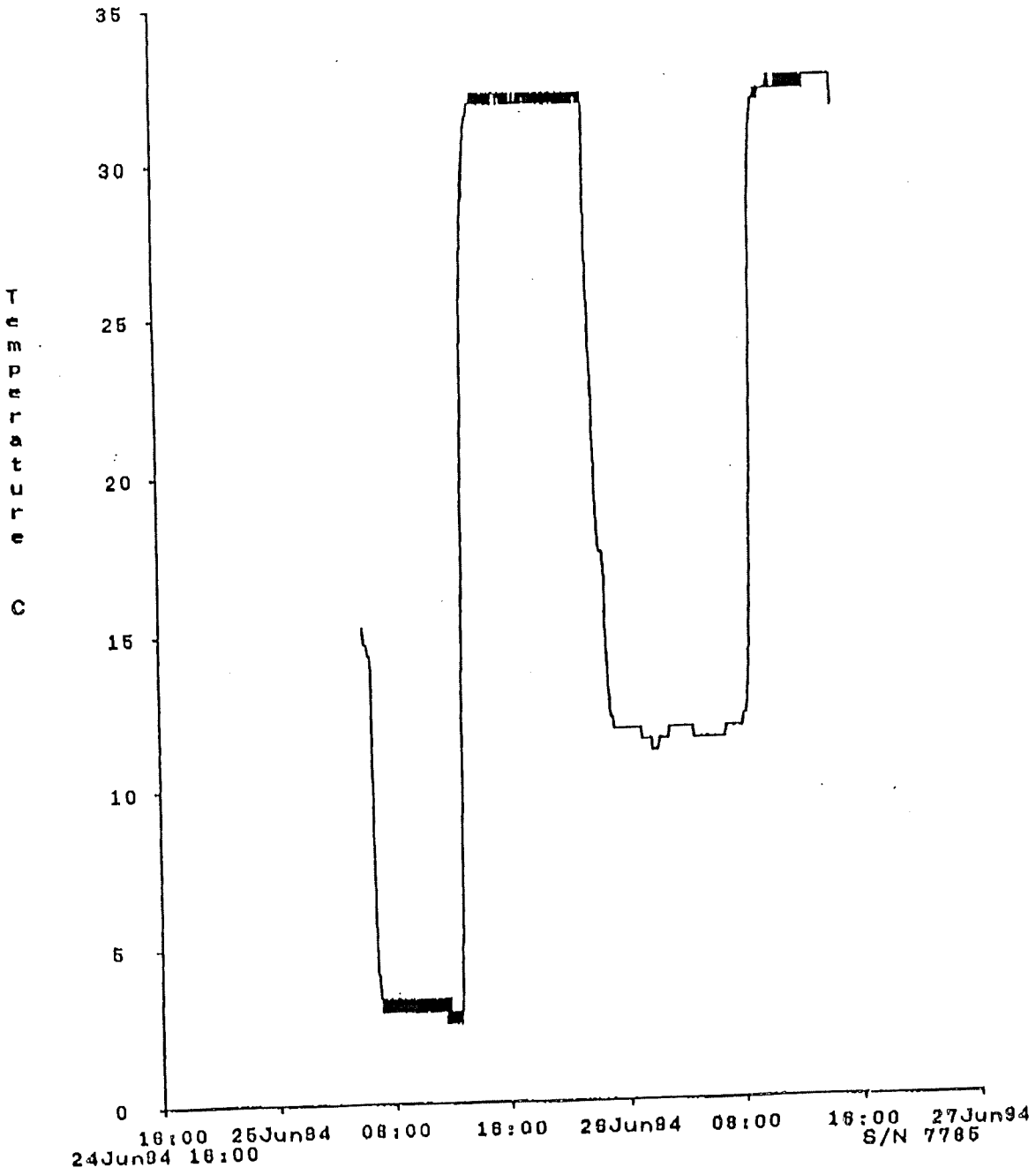


Figure 6.10.1b Temperature (^{0}C) recorded in the control box (wood-shavings, 4 holes, 500ml ice bottle) during the 30 hour simulation experiment.

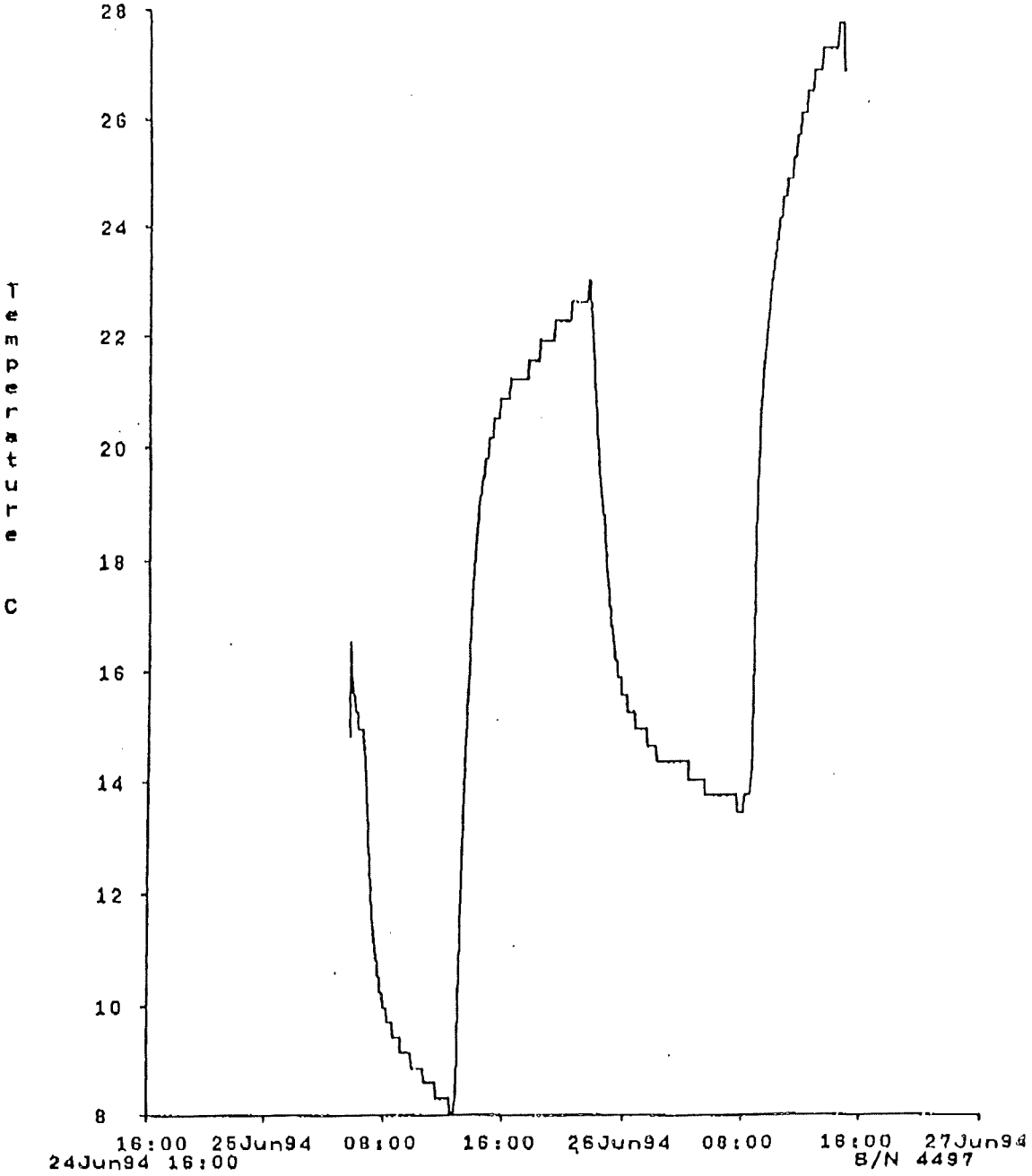


Figure 6.10.1c Temperature (°C) recorded in one of the test boxes (foam packing material, no holes, 500ml ice bottle) during the 30 hour simulation experiment.

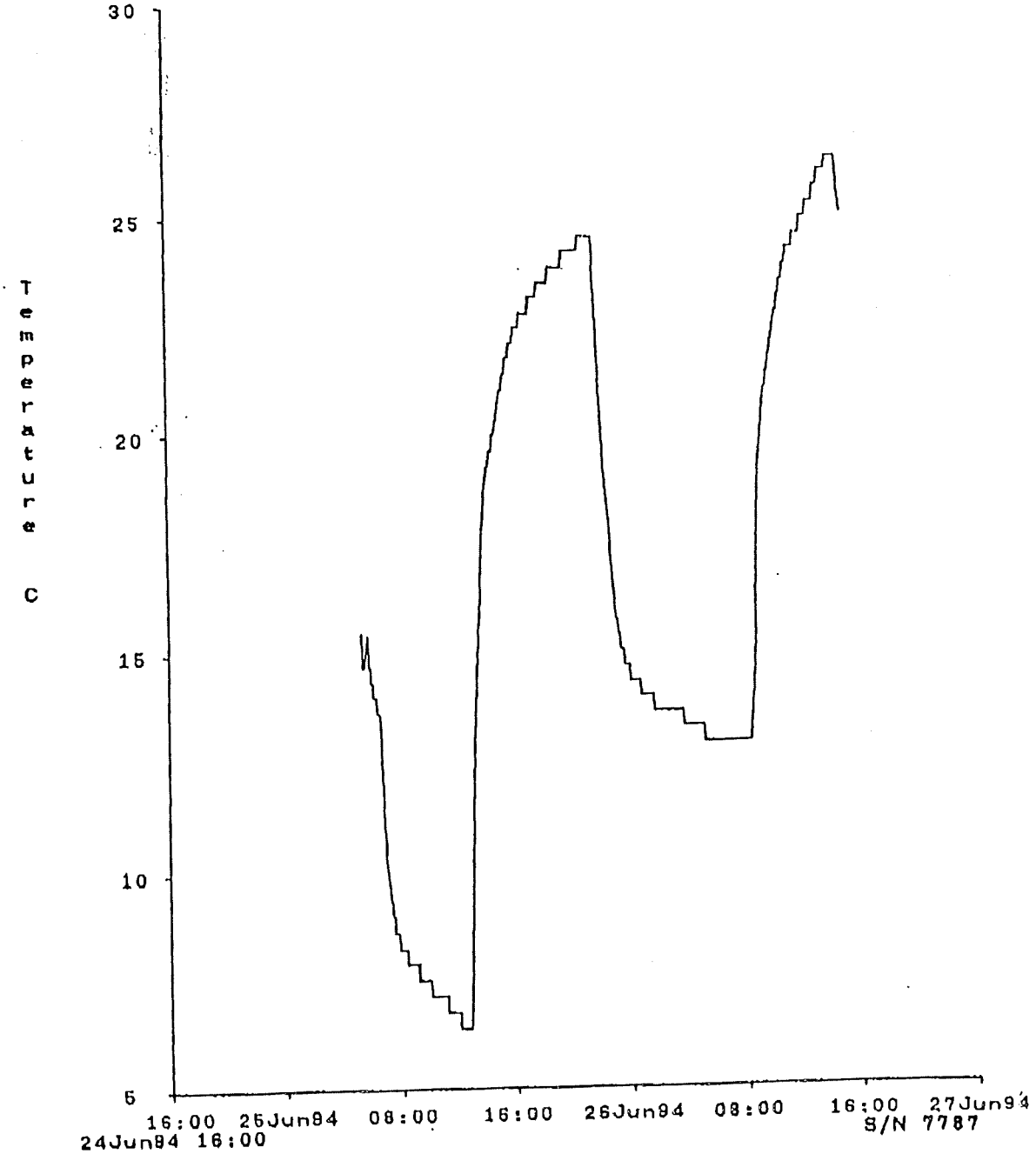


Figure 6.10.1d Temperature (°C) recorded in one of the test boxes (foam packing material, no holes, 500ml ice bottle) during the 30 hour simulation experiment.

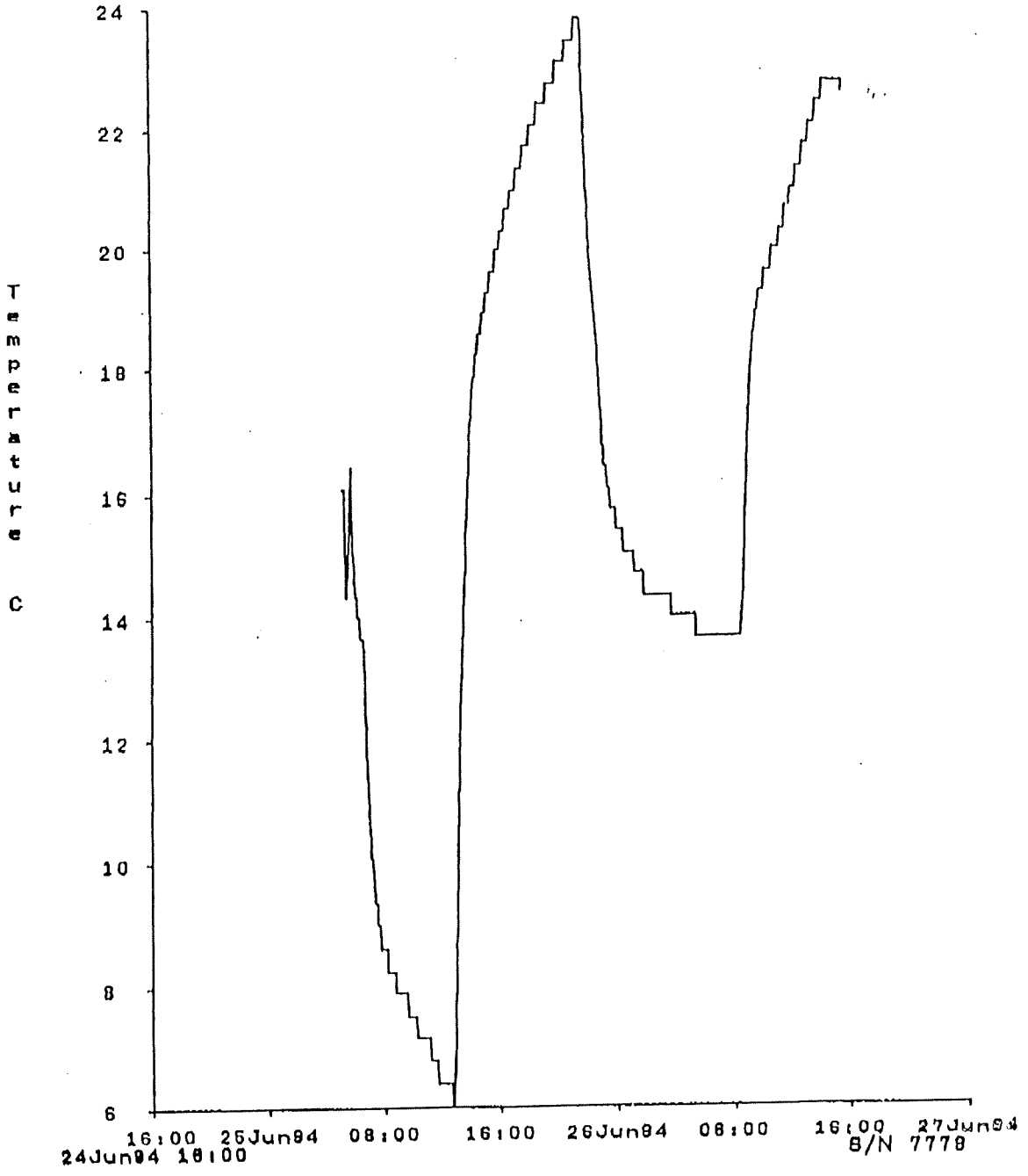


Figure 6.10.1e Relative humidity recorded in one of the test boxes (foam packing material, no holes, 500ml ice bottle) during the 24 hour simulation experiment.

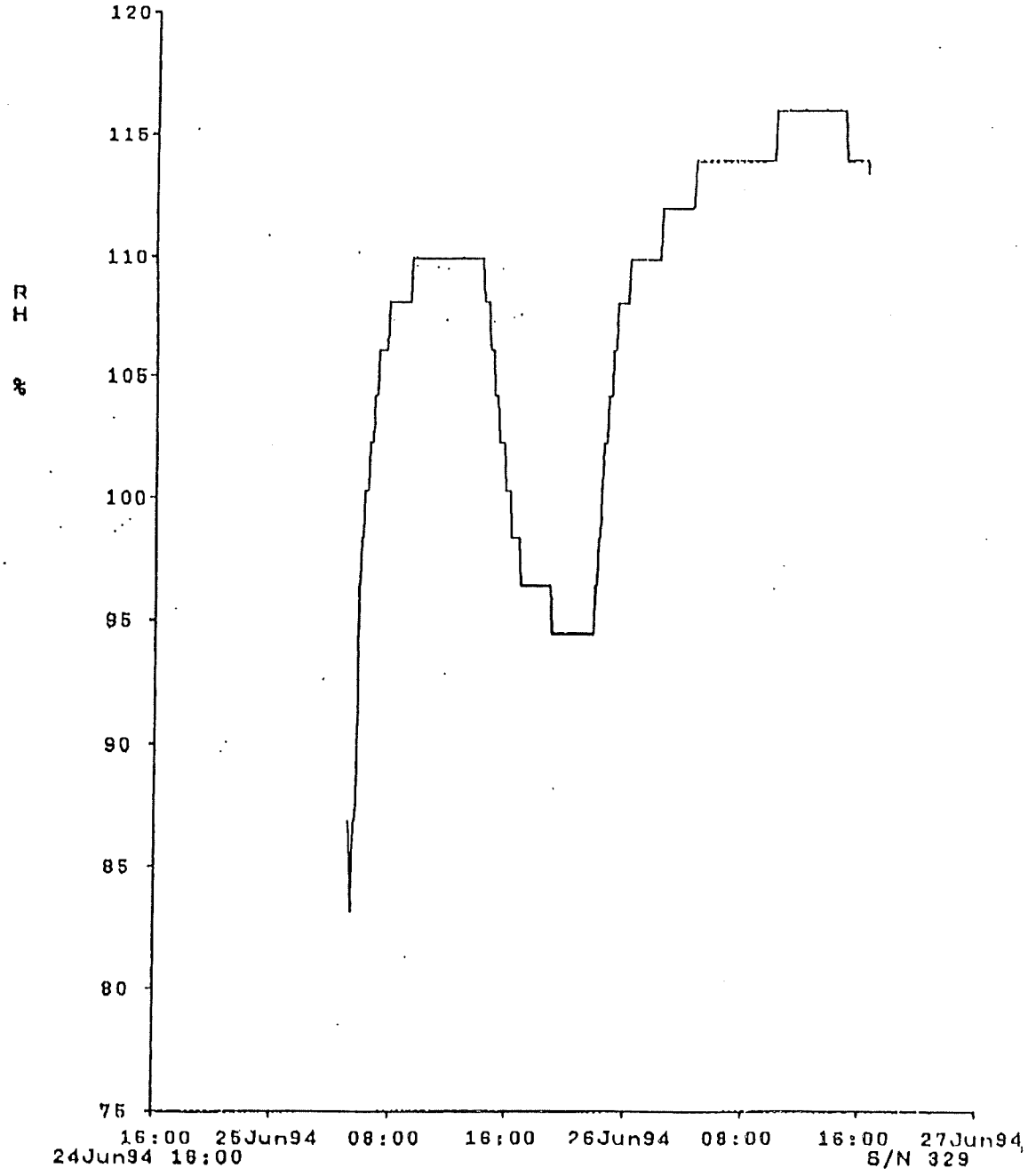
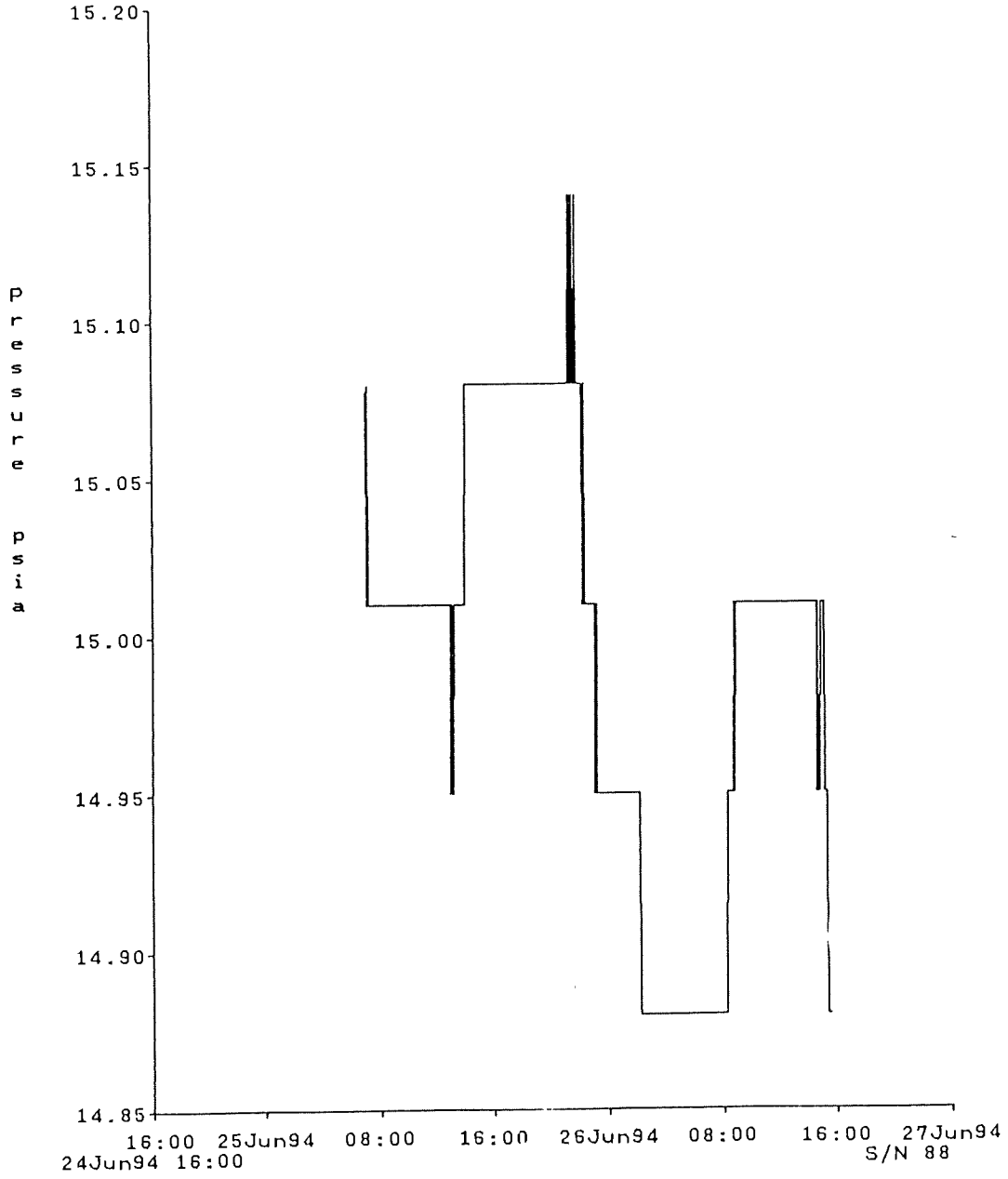


Figure 6.10.1f Pressure recorded in one of the test boxes (foam packing material, no holes, 500ml ice bottle) during the 30 hour simulation experiment.



6.11 Experiment 8: Control (500ml, 4 holes, Wood-shavings) v's 500ml, no holes, Woodwool

6.11.1 Results

Health status

All lobsters in the control box survived, with the health status being only 87% when unpacked (Table 6.11.1a), but recovering to 100% after 24 hours in a seawater tank (Table 6.11.1b). The survival and health status of the lobsters in the replicated test boxes was poor. Survival averaged 93% when unpacking, with an average health status of 51%. During the recovery period one more lobster died (ave: 91%), and 15 lobsters regained their health status (ave: 84%).

Table 6.11.1a Health status of lobsters immediately after unpacking, from the control box (500ml, 4 holes, wood-shavings) and the replicated test boxes (500ml, no holes, woodwool).

	Strong	Weak	Dead	Total	Strong %	Survival %
Test 1	6	9	0	15	40	100
Test 2	9	4	2	15	60	87
Test 3	8	6	1	15	53	93
Total	23	19	3	45	51	93
Control	13	2	0	15	87	100

Table 6.11.1b Health status of lobsters after a 24 hour recovery period in a seawater tank, from the control box (500ml, 4 holes, wood-shavings) and the replicated test boxes (500ml, no holes, woodwool).

	Strong	Weak	Dead	Total	Strong %	Survival %
Test 1	14	1	0	15	93	100
Test 2	12	1	2	15	80	87
Test 3	12	1	2	15	80	87
Total	38	3	4	45	84	91
Control	15	0	0	15	100	100

Statistical testing (G-test of independence with Yates correction of continuity, at 5% level) of the strong lobsters against weak and dead lobsters found that there was a significant difference immediately after unpacking (independence level G = 4.950) but not after a 24 hour recovery period in a seawater tank (independence level G = 1.678).

Environmental Factors

The ambient temperature recorded during the 30 hour simulation experiment ranged from 4.75°C - 33.00°C (Fig. 6.11.1a). The control box (500ml ice bottle, 4 holes, wood-shavings) had a temperature range of 8.25°C - 24.25°C (Fig. 6 11.1b), while the replicated test boxes (500ml ice bottle, no holes, woodwool) had a temperature range of 8.25°C - 25.25°C (Fig. 6.11.1c) and 9.00°C - 24.50°C (Fig, 6.11.1d). Thus, the temperature conditions were very similar.

The relative humidity recorded in the control box showed a relative humidity range of 82% to 98% during the simulation (Fig. 6.11.1e). Due to a malfunction of the logger, the relative humidity could not be recorded in one of the test boxes.

The pressure recorded in one of the test boxes showed pressure decreasing to 14.88 psia and increasing to 15.08 psia within the closed system (Fig. 6.11.1f). The pressure readings were noted as fluctuating proportionately to the ambient temperature.

6.11.2 Discussion

Statistical testing found that there was a significant difference in the health status of 15 lobsters immediately after unpacking, when comparing the two treatments. The use of wood-shavings and punching 4 holes into the box was significantly better than using woodwool with no holes punched into the boxes.

After a 24 hour recovery period though, the lobsters health status had improved sufficiently for statistical testing to determine independence between the health status of the lobsters and the treatment groups.

The improvement in the lobsters after a 24 hour recovery period suggests that the lobsters were highly stressed by the conditions they were

subjected to. The relative humidity was adequate for the lobsters to carry out some gas exchange, though the temperatures were quite high. The temperature recorded in the control box was no different from the test boxes, even with holes in the control. Thus, it is likely that the woodwool did not provide as much support for the lobsters or help to insult the box as well as the wood-shavings.

6.12 Summary and Recommendations

In terms of survival and health status, the control box (foam box with 4 holes, dry wood-shavings and a 500ml ice bottle) performed significantly better than the alternative suggestions used in each test.

The only time there was no significant difference in the strength of the lobsters used was when wood-shavings and woodwool were compared after a 24 hours recovery period in a seawater tank. The survival and health status of the lobsters after the 24 hours recovery was 91% and 84% respectively, which was still well below accepted industry standards of 95%+ survival.

Thus, the packing system used as the control (packing lobsters in a foam box with wood-shavings, a 500ml ice bottle and 4 holes punched into the box) is recommended to processors above woodwool, hessian or foam packed with no holes punched in the boxes and a 500ml ice bottle.

The control used in experiments 6 - 8, testing a 500ml ice bottle with wood-shavings and 4 holes punched into the boxes, showed that survival of the lobsters was always 100%, both immediately after unpacking and after a 24 hour recovery period in a seawater tank. The lobsters health status was 94%, 100% and 87% immediately after unpacking, and 100%, 93% and 100% after the 24 hour recovery period in experiments 6 - 8 respectively.

This backs up experiments 2 and 3 where the recommendations suggest the decreasing in size of the ice bottles dominantly used in the western rock lobster industry (1000ml). The lobsters survival in the control used in experiments 6 - 8 was just a good as the survival of the control lobsters during the first 5 experiments.

Figure 6.11.1a Ambient temperature (^{0}C) recorded during the 30 hour simulation experiment.

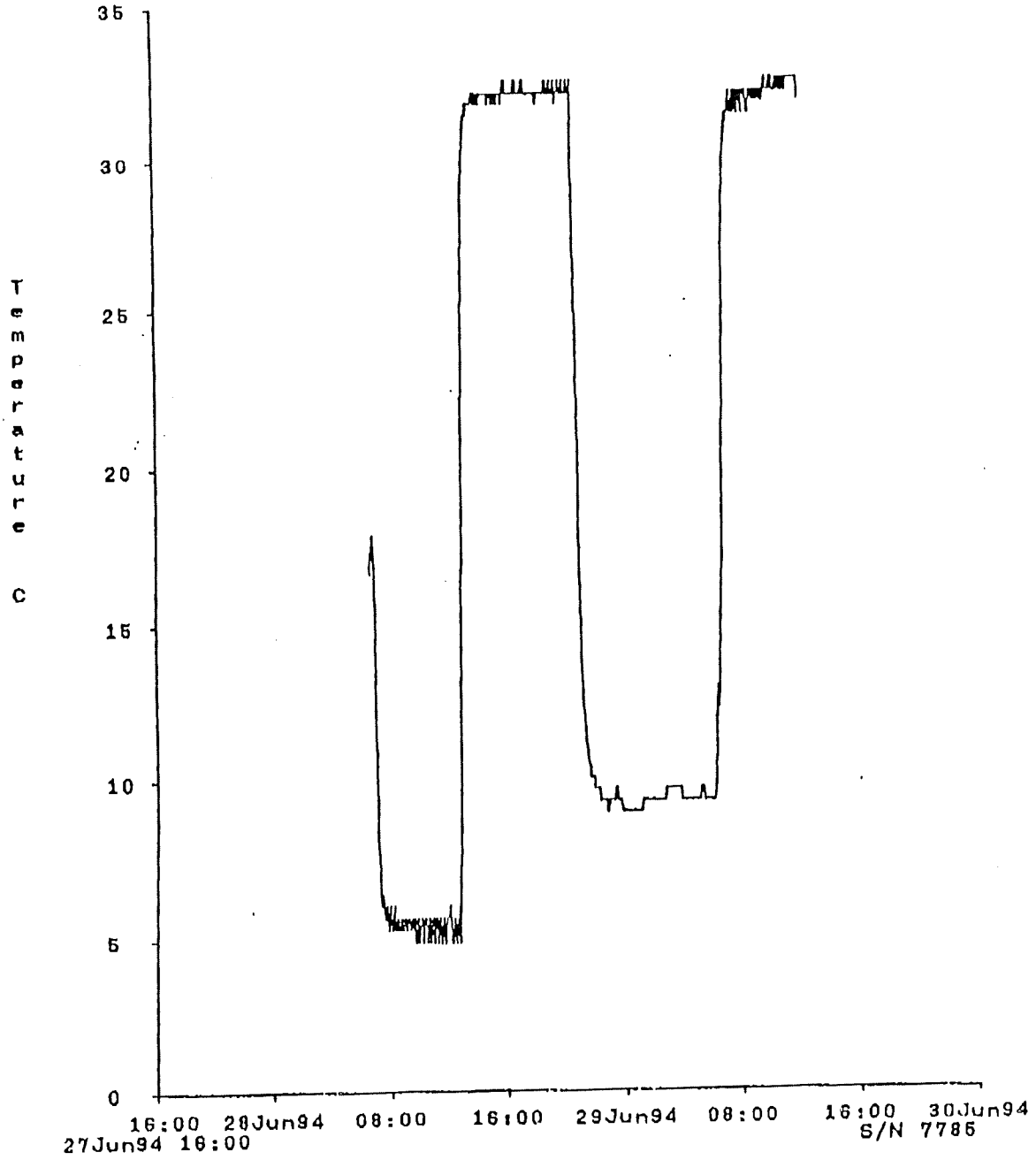


Figure 6.11.1b Temperature (°C) recorded in the control box (500ml, 4 holes, wood-shavings) during the 30 hour simulation experiment.

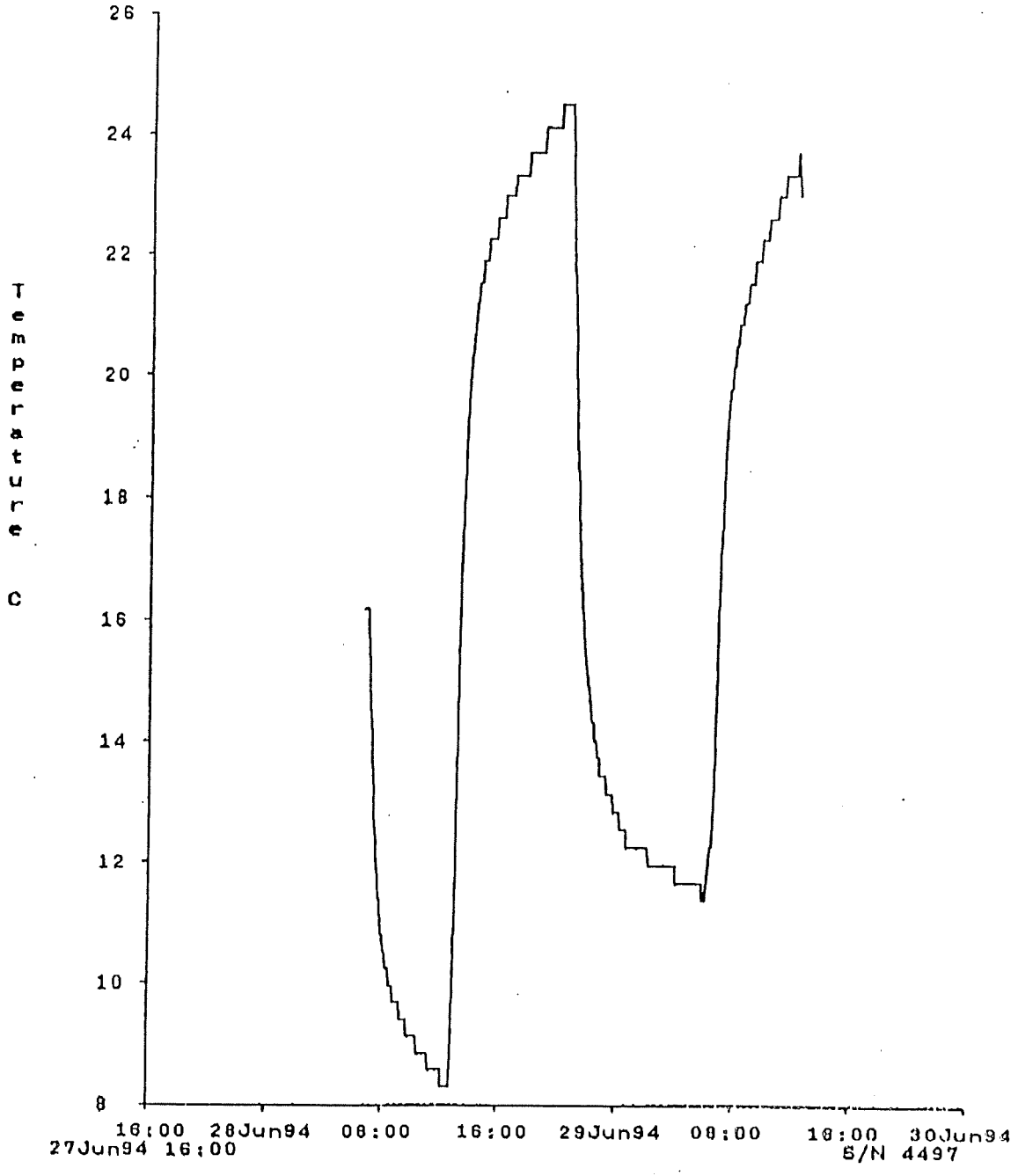


Figure 6.11.1c Temperature (°C) recorded in one of the test boxes (500ml ice bottle, no holes, woodwool) during the 30 hour simulation experiment.

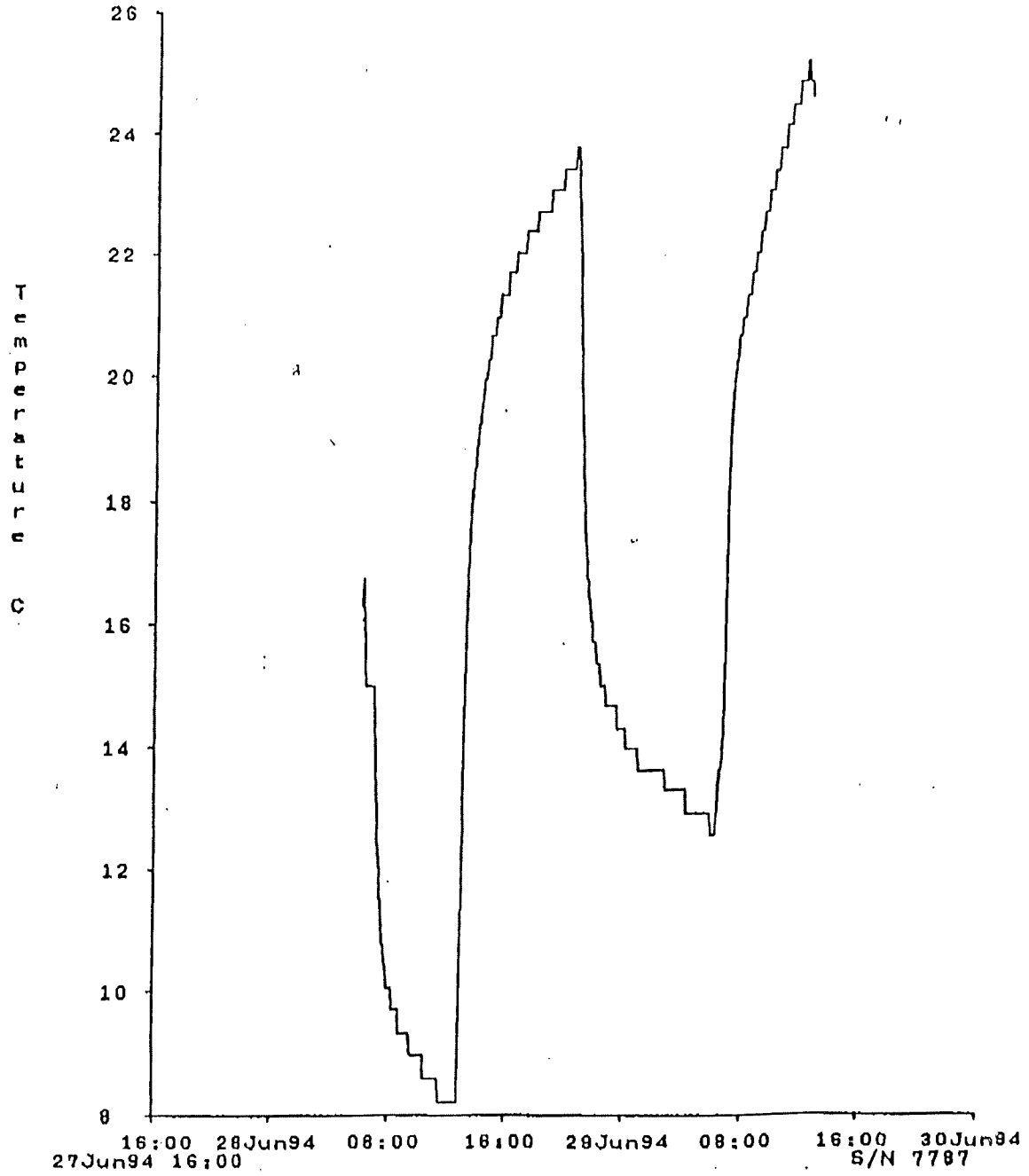


Figure 6.11.1d Temperature (^{o}C) recorded in one of the test boxes (500ml ice bottle, no holes, woodwool) during the 30 hour simulation experiment.

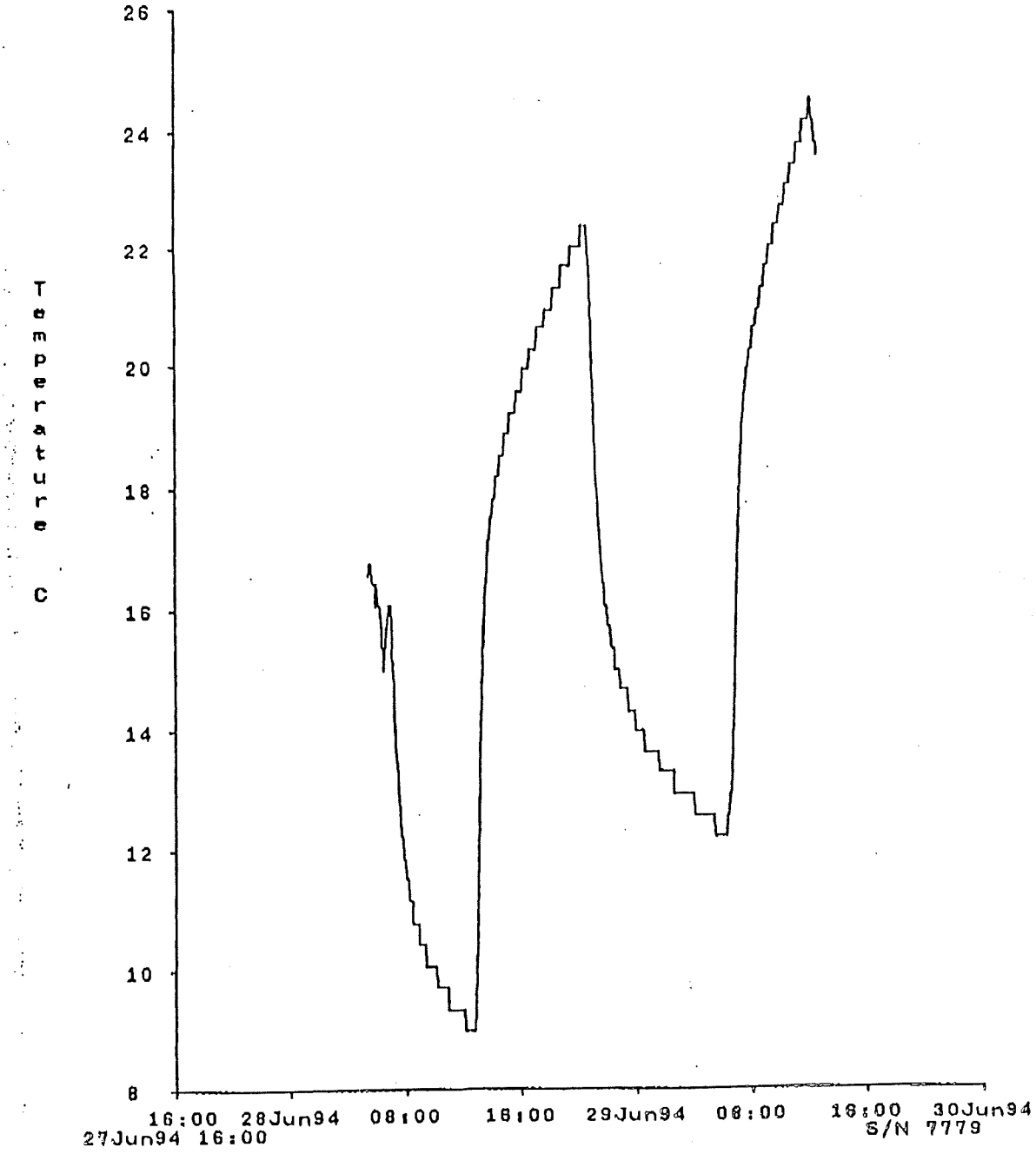


Figure 6.11.1e Relative humidity (%) recorded in one of the test boxes (500ml ice bottle, no holes, woodwool) during the 30 hour simulation experiment.

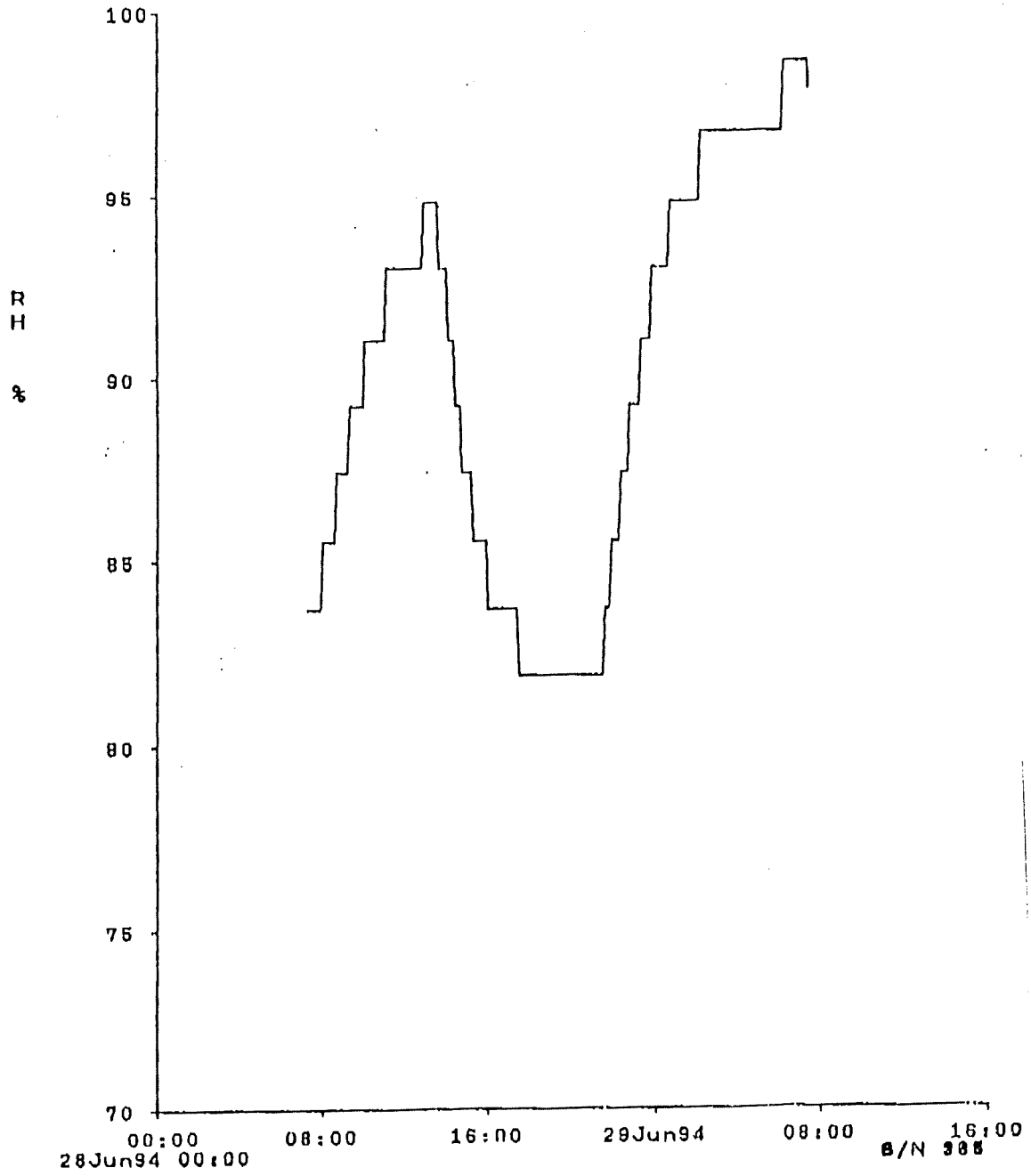
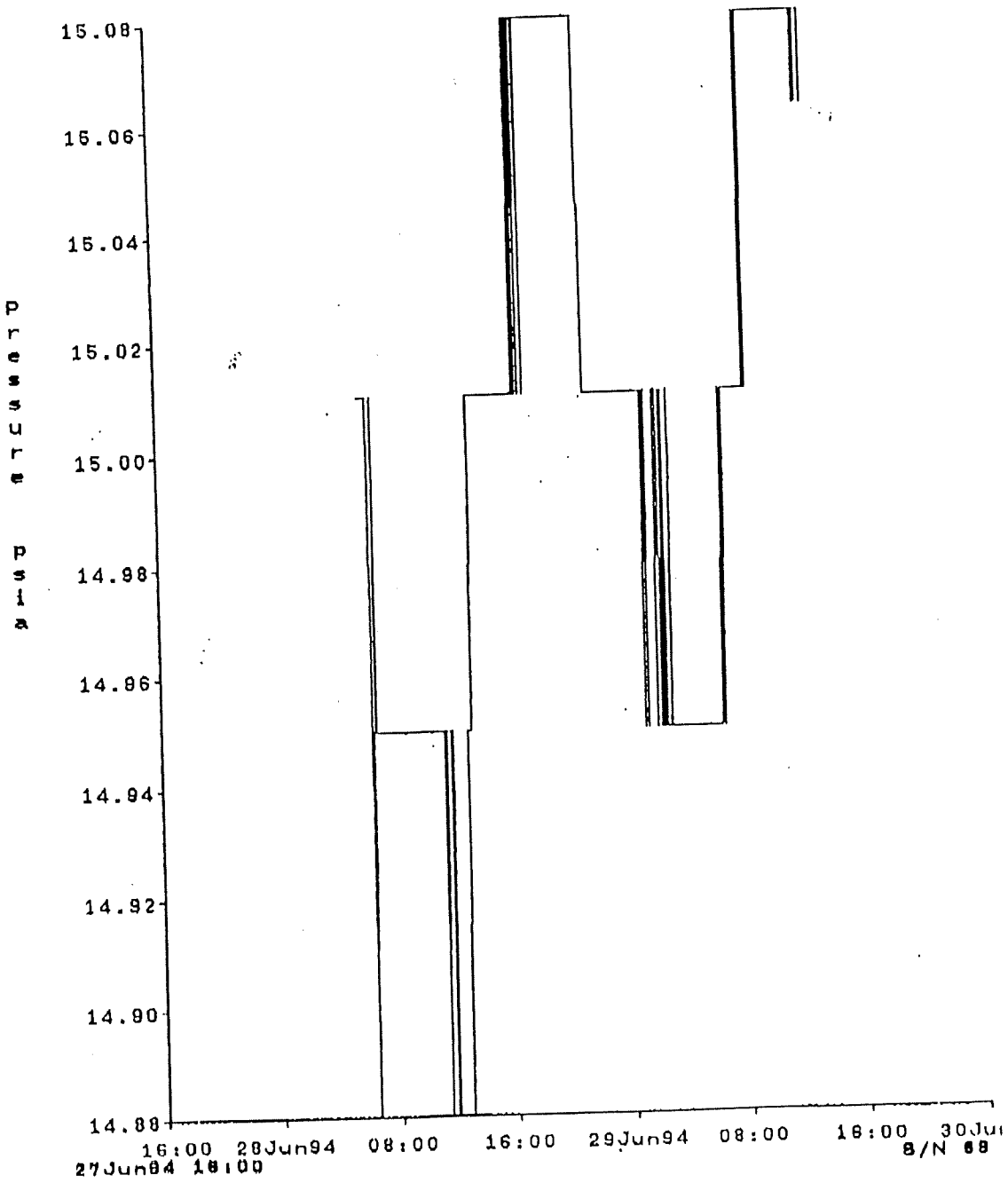


Figure 6.11.1f Pressure (psia) recorded in one of the test boxes (500ml ice bottle, no holes, woodwool) during the 30 hour simulation experiment.



7. PHYSIOLOGICAL LIIMITATONS - OXYGEN CONSUMPTION AND TEMPERATURE

7.1 Introduction

Oxygen consumption which relates directly to the metabolic rate, is known to be affected by many factors in crustaceans, eg age, size, sex, moult stage, temperature, relative humidity, activity, nutritional state, stress and by hormonal and nervous system factors. Any or all of these factors may affect the manner in which a crustacean such as a western rock lobster responds when exposed to air during transport.

Lisac (1986), for live lobsters from the Carribean, recommended maintenance of low temperatures between 1 and 7^{o}C, to render lobsters dormant, resulting in a lower metabolic rate and thus a reduced demand for oxygen. Lowering of temperature in crustaceans also increases the oxygen affinity of the crustacean blood by assisting oxygen transport from air (Whiteley et al 1990).

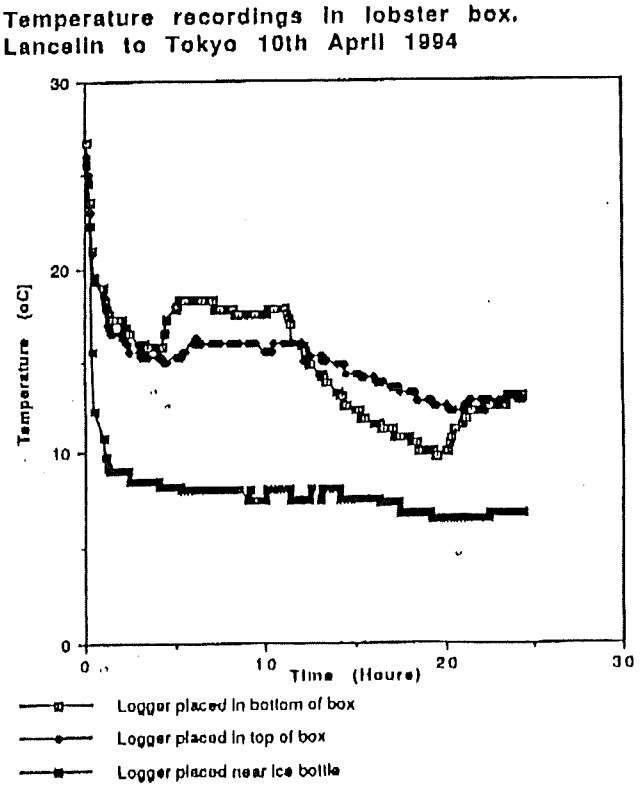
Temperature increases during live aerial transport have been shown to lead to increases in metabolic rate, which is temperature dependent in crustaceans (Ulgow et al 1988).

This research segment was undertaken:

to verify that metabolic rate and hence oxygen demand was temperature dependent in the western lobster and ;

to illustrate the benefits of lower temperatures during transport.

It had previously been determined by tracking a packed rock lobster box from Lancelin, WA to Tokyo on the 10.4.94, that during the transport process (which took 25 hours, from packout in Lancelin to unpack and retank in Tokyo), that the temperature range to which western rock lobsters were exposed, was from 7 to 28^{o}C.



7.2. Materials and Methods

Lobsters were obtained form a Fremantle processing facility, packed in a foam esky according to the industry standard for the 1993/94 season (2 holes in box, one either end, wood shavings, 1 l ice bottle) and transported 26 km to the Curtin University of Technology Aquaculture Centre. Upon arrival at the Aquaculture Centre, they were unpacked and placed into 5000 litre recirculating sea water system maintained at temperatures around 23^{o}C ± 5^{o}C, for 8 weeks. Lobsters were maintained by feeding once a day a diet of chopped mussels, white bait and trout starter pellets, at a rate of 5% body weight per day. Prior to experimentation lobsters were purged by placing them into 2000 litre seawater tanks with an exchange rate of 2000 litres an hour for 4 days prior to experimentation. This was undertaken to prevent them fouling the metabolic chamber with faeces. Lobsters are purged in commercial processing facilities for at least 2-3 days prior to packing and transport, thus a 4 day purging period replicates that which occurs in commercial practice.

Lobsters were removed from the purging tank, dip netted and placed into a 20 litre polystyrene container and covered with an old damp towel which had been saturated with water. The towel and water selected were free from contact with phosphates present in washing powders which affect lobsters. Lobsters were then transported to the experimental laboratory.

Testing was performed via a Taylor 'Servomex' (OA 11184), a two channel paramagnetic oxygen analyser and associated leeds and Northrup 'Speedomax' potentiometric trace recorder. Dry, carbon dioxide free air was filtered through an air tight, sealed container at a set rate and then freed of carbon dioxide and water again before it passed to one of the 'Servomex' channels, where it was compared against a sample of reference air which was assumed to be 100%saturated with O_2. The trace recorder measured the difference in oxygen between the sample air and the air which passed through the chamber.

A modified acrylic zooplankton sampler (internal diameter 141 mm, length 393 mm) was used as an experimental chamber. An air tight seal was achieved using petroleum jelly and elastic bands. The chamber was fitted with plastic mesh to provide a substrate for the lobster to grasp. The chamber was of such dimensions that any movement of the lobster was restricted and activity minimal. Two holes were present in the chamber, one to carry compressed air into the chamber and the other, returned air, passed through the chamber to the Servomex to be analysed.

Each test was run for 24 hours within a 'Levatron' temperature controlled incubator (model 102, range 5 - 40^{o}C) under dark conditions to keep disturbance and stress to a minimum. Lobsters were transported to the laboratory under dark conditions.

Pilot studies prior to experimentation with lobsters, had been undertaken to determine the suitability as the equipment had only been used for small mammals and birds, which have much greater metabolic rates than decapod crustaceans. Flow rate through the chamber was originally set at 400 cm^3 / minute with a ratio range of 16-21 %, a standard setting for birds and mammals. These setting proved to be unsuitable for western rock lobster and

a series of trial and error adjustments were made to increase the distance in the trace line from the zero graduation. The best test settings were found to be a flow rate of 200 cm^3 / minute and a ratio of 20-21%.

Three temperatures were originally selected, 10^o, 20^o and 30^oC. As the first lobster died at 30^oC later the temperature of 25^oC was used instead of 30^oC. Three tests were undertaken at each temperature with no acclimation time, as lobsters during live transport in reality receive no acclimation considerations.

The Servomex produced a curve of the amount of oxygen used. To calculate the area under the curve (which equals the amount of oxygen used), a Tamaya Digital Planimeter, 'Planix 7' was used (area was measured in square inches). Incubator, air temperatures and air pressures were taken hourly,with Hasting Data Loggers (Hobos) for use in calculating the metabolic rate according to the following formula;

$$FR \times \frac{273}{273 + T_a} \times \frac{P_a}{760} \times \frac{60}{M} \times \frac{\Delta O_2}{100 - (20.94 - \Delta O_2)} \times 4.8 \times 4.184 = J/g/hr$$

where
- FR = Flow rate
- T_a = Temperature of air
- P_a = Pressure of air
- M = Mass of lobster
- ΔO_2 = Percent oxygen used
- = area underneath the trace / 10 x).94

(Animal Physiology 401 Laboratory Manual)

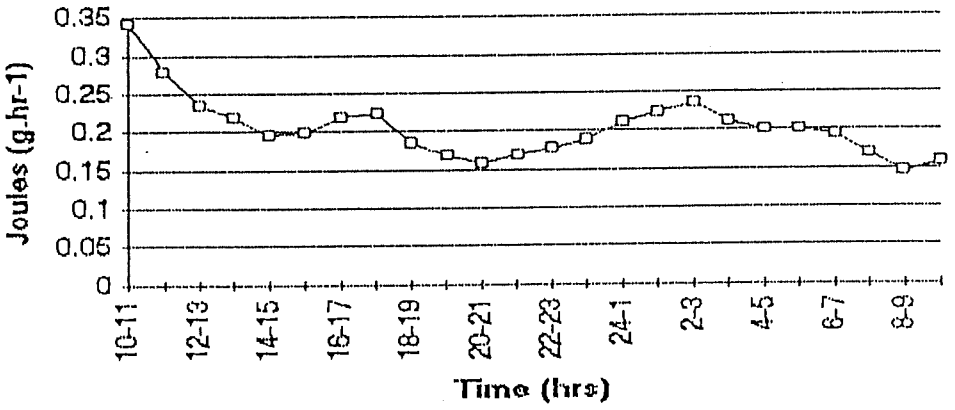
On completion of the experimentation the lobster was removed from the chamber and its health assessed (movement, missing appendages). The presence of liquid in the chamber and its smell was also noted. The lobster was then taken back to the Aquaculture Centre, released into the holding tank and its behaviour on release (flapping, swimming, and its movement in the bottom of the tank) recorded.

7.3 Results

7.3.1 Metabolic rate at 10°C 24 Hour Test

7.3.1.1

Metabolic Rate for *Panulirus cygnus*
held at 10°C for 24 Hours
Test I



Lobster Weight	683 gm
Metabolic Rate	0.49 ± 0.29 J / g / hr 0.15 - 0.35)
Date	31.8.94 - 1.9.94

Diurnal variation present in trace between 2300 and 0300 hrs, shown by a change in the pattern of the trace. Also observed on the metabolic rate graph as a rise from 0.16 J / g / hr between 2000 - 2100 to 0.24 between 02 00-0300, where it peaked and then began to decrease. This is consistent with reports that lobsters are active nocturnal foragers.

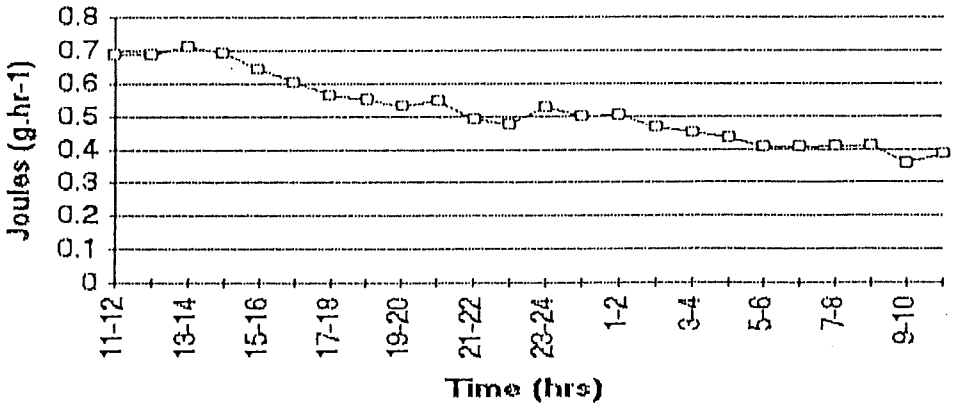
A general downward trend in metabolic rate.

Notes on removal from chamber.

Lobster very subdued, little or no movement when removed from the chamber. Reacted well to water movement and flapped as soon as contact was made with water.

7.3.1.2

Metabolic Rate for *Panulirus cygnus* held at 10°C for 24 Hours Test 2



Lobster Weight	607 gm
Metabolic Rate	0.54 ± 0.18 J / g / hr
	0.36 - 0.72
Date	19.9.94 - 20.9.94

Slight diurnal variation presented between 2200 - 2300 where it rose from 0.48 J / g / hr to 0.53 J / g / hr 2300 - 0600, and then a gradual decline to 0.41 J / g / hr at 0500 - 0600. A definite change in trace pattern took place between 2300 and 0600.

There was a gradual decrease in metabolic rate over the testing period.

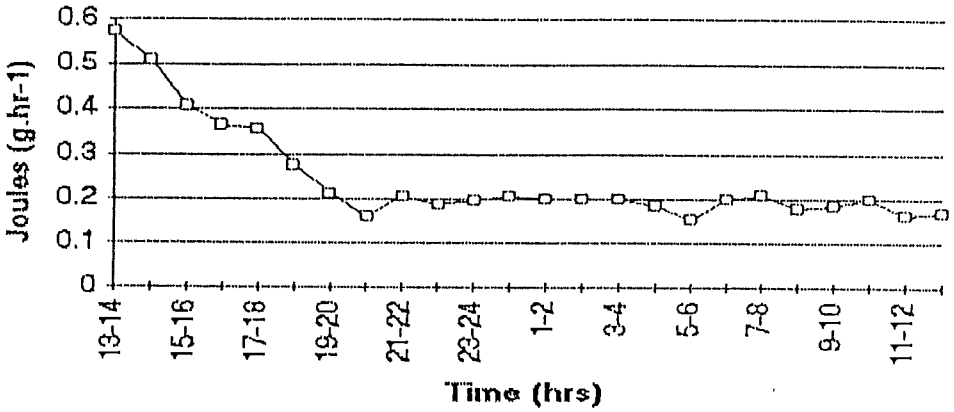
Incubator temperature was originally elevated and this may have attributed to the high metabolic rate obtained compared to the 2 other 10°C tests. The high temperature may have caused an increase in metabolic rate. It would have taken some time for the lobster to recover and for its metabolic rate to be lowered. Inadvertently shows the effect of having a high initial temperature and then the effect of cooling on metabolic rate.

Notes on removal from chamber.

Lobster was passive when removed from chamber, but became active when placed into the holding tank.

7.3.1.3

Metabolic Rate for *Panulirus cygnus* held at 10°C for 24 Hours Test 3



Lobster Weight	652 gm
Metabolic Rate	0.36 ± 0.21 J / g / hr
	0.15 - 0.57
Date	20.9.94 - 21.9.94

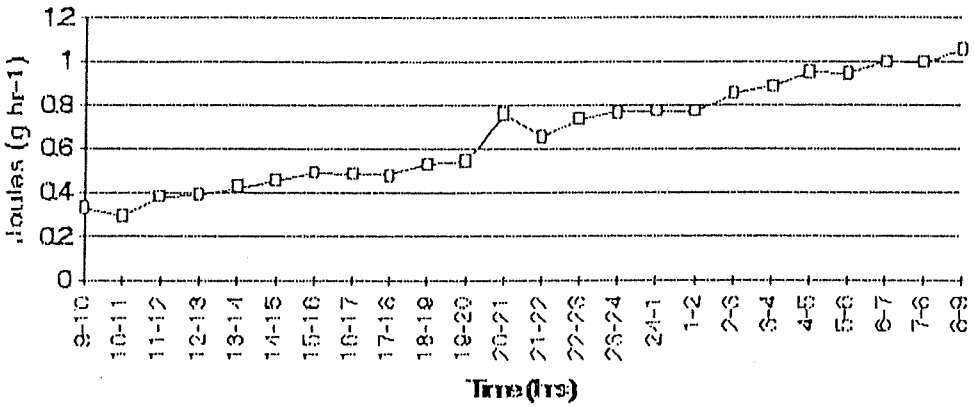
Diurnal variation was present between 2000 and 2100 where it began to rise. It peaked at 0.20 at 2100 - 2200 staying elevated until 0300 - 0400 when it began to decrease until 0500 - 0600. Trace reading showed a change in pattern between 2100 and 0800 hrs.

Notes on removal from chamber.

Lobster appeared weak, yellow / black water fluid was present in base of chamber. Lobster recovered well once re-immersed in water.

7.3.2.1

Metabolic Rate for *Panulirus cygnus* held at 20°C for 24 Hours
Test I



Lobster Weight	595 gm
Metabolic Rate	0.68 ± 0.38 J / g / hr
	0.29 - 1.06
Date	2.8.94 - 3.8.94

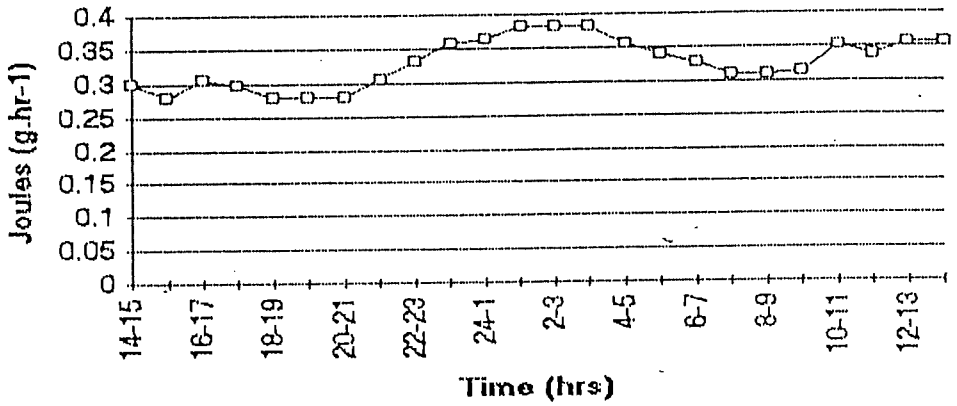
No distinct diurnal variation can be seen. There is a jump in metabolic rate between 2000 - 2100 and 2100 - 2200. Trace readout shows a change in pattern between 2300 - 2400 which continues until 0400 - 0500 when the pattern returns to normal.

Notes on removal from chamber.

Lobster was vigorous and resisted handling. Once returned to holding tank it flapped and sank to the bottom where it moved normally.

7.3.2.2

Metabolic Rate for *Panulirus cygnus* held at 20°C for 24 Hours Test 2



Lobster Weight	655 gm
Metabolic Rate	0.33 ± 0.14 J / g / h
	0.28 - 0.38
Date	31.9.94 - 14.9.94

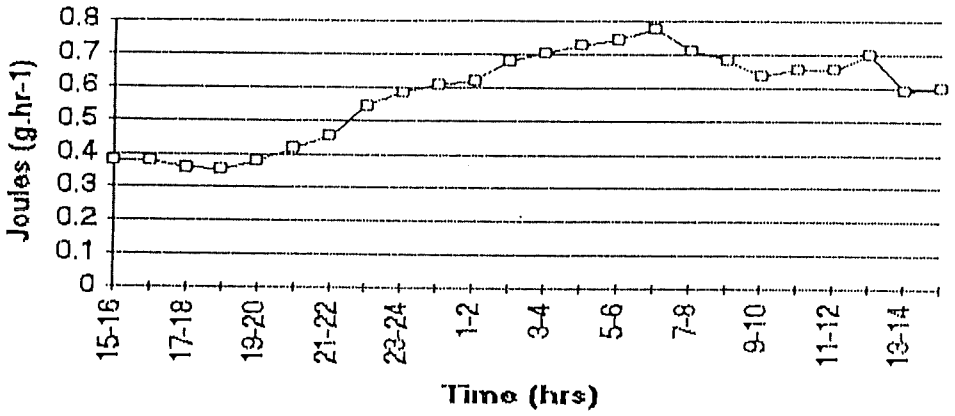
Overall increase in metabolic rate over the test period. Diurnal variation present between 0200 - 2100 when metabolic rate increased until it peaked at 0200 - 0300 and then gradually decreased until 0700 - 0800

Notes on removal from chamber.

Lobster was active and healthy when removed from chamber and flapped once in contact with water from the holding tank.

7.3.2.3

Metabolic Rate for *Panulirus cygnus*
held at 20°C for 24 Hours
Test 3



Lobster Weight	697 gm
Metabolic Rate	0.54 ± 0.18 J / g / hr
	0.36 - 0.73
Date	13.9.94 - 14.9.94

General increase in metabolic rate over testing period

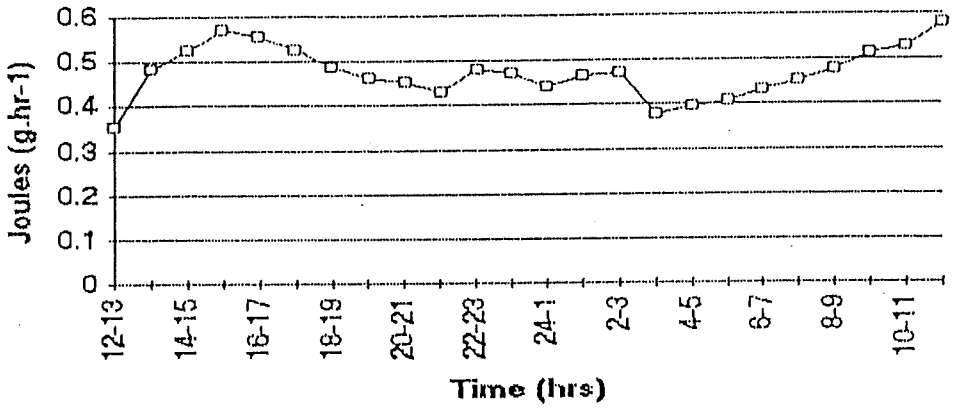
Diurnal variation was present between 2100 - 2200 after which there was a sharp rise in metabolic rate, peaking at 0600 - 0700 and then falling. Readout shows a change in trace pattern between 2200 - 0700.

Notes on removal from chamber.

When removed it was thought that the animal was dead. There was a strong noxious odour as well as a black watery fluid present in the base of the chamber. It was not until water was run over the animal (to remove the black fluid) that it moved. Animal was very weak and was not placed back into the holding tank. The black liquid was maybe a stress response (melanosis), or possibly a problem with the animal not being purged completely and faeces mixing with condensation in the chamber (faeces would have produced ammonia which is toxic to the animal. This may explain the weakness of the animal). Gases given off during the oxidation of excreted matter would increase ventilation rates of the animal . This would have been reflected in increased metabolic rates.

7.3.3.1

Metabolic Rate for *Panulirus cygnus* held at 30°C for 24 Hours Test I



Lobster Weight	717 gm
Metabolic Rate	0.47 ± 0.18 J / g / hr
	0.35 - 0.58
Date	2.8.94 - 3.8.94

Diurnal variation could be distinguished from the graph between 2200 - 2300 to 0400 - 0500 when metabolic rate dropped.

Test resulted in lobster mortality. It is difficult to ascertain when the lobster died during the test as the trace never reached zero graduation on the readout. It is possible that either it died between 1100 and 1200 and the air had not reached the Servomex or that the animal died between 0200 and 0400 and defecated, when a sharp decrease in metabolic rate can be seen after a gradual decrease was experienced. The remainder of the reading was then the faeces oxidizing.

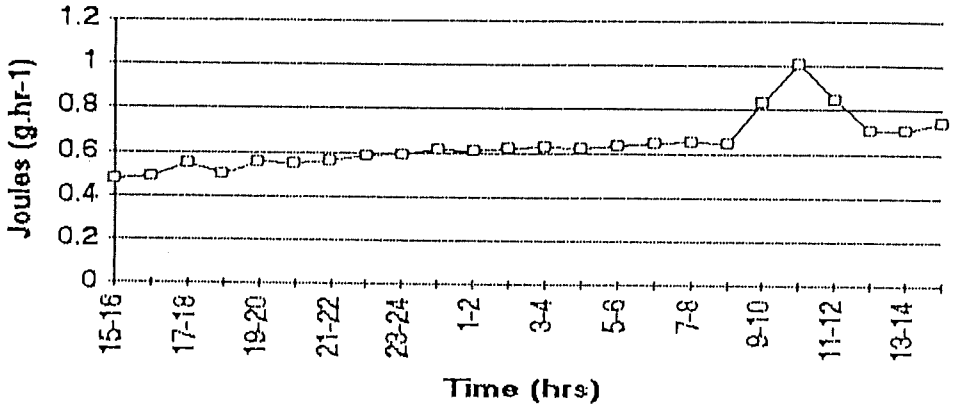
As the animal died at 30°C it is assumed that this was above the upper temperature tolerance level for western rock lobster after a time period in excess of 12 hrs and it was therefore decided to reduce the maximum testing temperature to 25°C.

Notes on removal from chamber.

Lobster dead. Presence of strong noxious odour and a yellow non viscous fluid tinged with black green. Odour suggested lobster had been dead for a considerable period.

7.3.4.1

Metabolic Rate for *Panulirus cygnus* held at 25°C for 24 Hours Test I



Lobster Weight	666 gm
Metabolic Rate	0.74 ± 0.24 J / g / hr
	0.47 - 1.01
Date	21.9.94 - 22.9.94

No diurnal variation was observed, but on the readout the trace line became much flatter during the period between 1900 - 0500.

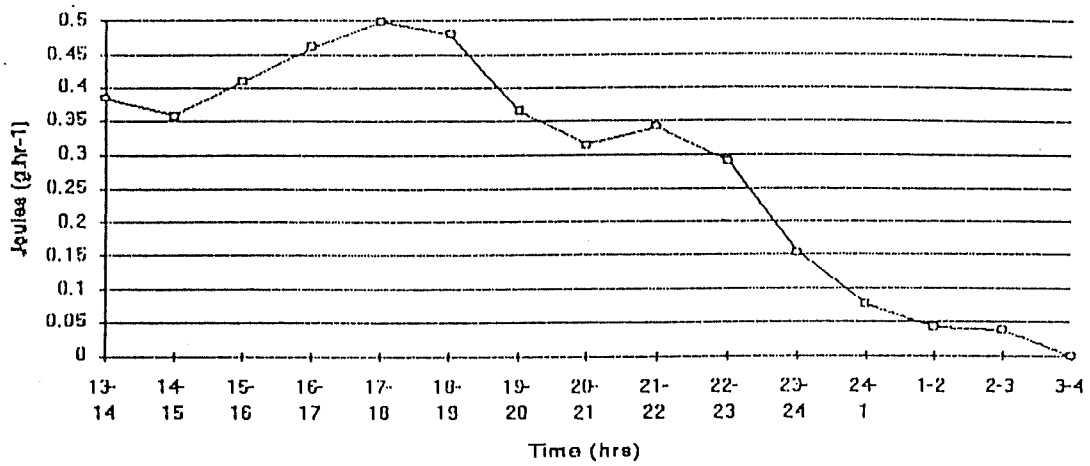
A sudden leap in metabolic rate was noted between 0900 and 1200. A possible explanation is that the lobster was stressed in some form, ie someone opened the incubator door, the incubator was knocked, or it may have been the lobster's reaction to some internal stress.

Notes on removal from chamber.

Lobster was stressed when removed from the chamber. It had shed a leg, but was active.

7.3.4.2

Metabolic Rate for *Panulirus cygnus* held at 25°C for 24 Hours Test 2



Lobster Weight	650 gm
Metabolic Rate	0.25 ± 0.25 J / g / hr
	0.00 - 0.50
Date	22.9.94 - 23.9.94

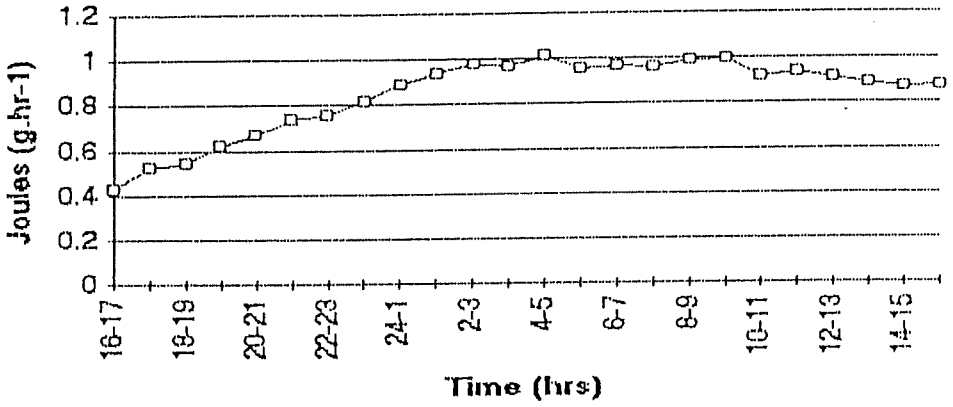
No diurnal variation was noted as the lobster died at 0300 hrs. Metabolic rates had been reducing until then. No obvious reason for death. A possibility could be that either the animal was not purged sufficiently and defecated (the oxidising faeces may have produced toxic gases) or was not healthy at the time of testing and the added stress of testing caused mortality.

Notes on removal from chamber.

Lobster was dead. Noxious odour was present along with the presence of a small amount of yellow black non-viscous liquid.

7.3.4.3

Metabolic Rate for *Panulirus cygnus* held at 25°C for 24 Hours Test 3



Lobster Weight	656 gm
Metabolic Rate	0.72 ± 0.21 J / g / hr
	0.43 - 1.02
Date	23.9.94 - 24.9.94

Metabolic rate increased over testing time.

No diurnal variation observed. Readout shows a differing pattern in respiration between 1900 - 0500.

Readings peaked at 0400 and then began to steadily decrease.

Notes on removal from chamber.

Lobster was healthy and vigorous, moving in hands when removed from the chamber and flapping vigorously once tail was in touch with the water from the holding tank.

7.4. Discussion and Conclusions

The Servomex and the methodology used in this experimentation, proved to be useful in gaining some insight into the relationship between temperature and oxygen consumption on the metabolic rate of live western rock lobsters in the size range 607 - 717 gm.

Experimentation at 10^{o}C showed that metabolic rate was gradually reduced at this temperature over the 24 hour period. At the completion of the experimentation period lobsters in the test chamber were subdued showing little activity but reacted well to water and recovered quickly when re-immersed in sea water. One of the three test lobsters appeared weak on removal from the test chamber, which contained some yellow/black fluid, but recovered once re-immersed in water. The reason for its health status was unknown, other than maybe it sustained some damage during handling. A change in the Servomex trace pattern occurred with all three lobsters at some time between 2000 and 0300 hrs, indicating that in spite of being maintained in constant conditions of light humidity and temperature, a diurnal activity pattern as occurs in the natural environment when lobsters are active and forage, still exists. This is an interesting and not entirely unexpected result.

One test at 10^{o}C inadvertantly commenced at a higher temperature than the other two (7.3.1.2). A high initial metabolic rate was observed, followed by a gradual reduction, a good demonstration of the benefits of cooling to 10^{o}C prior to live transport of western rock lobster.

Experimentation at 20^{o}C for all 3 test animals showed a gradual increase in metabolic rate over the 24 hr period. Two of three test animals showed a diurnal increase in metabolic rate between 2000 and 0300 hrs. Two of the three test animals at the end of the 24 hour test period were in good condition and active once returned to the sea water tank. The other lobster was inactive and there was a noxious odour, as well as some black watery fluid present in the base of the chamber. The animal moved on washing with water but was judged as nearing death and killed. It is suggested that the black liquid is either a stress response (melanosis) or that the animal was not completely purged and defecated in the test chamber.

It was originally planned to conduct three tests at 30^{o}C, however one test was undertaken and the lobster died, thus the experimentation was not repeated but rather 3 tests at 25^{o}C undertaken. On opening the chamber for this test, a strong noxious odour was present as was a yellow non viscous fluid, tinged with a black green colour. This experiment at 30^{o}C suggested that this temperature was beyond the thermal tolerance for western rock lobster for a 24 hr period.

Experimentation at 25^{o}C showed a gradual increase in metabolic rate for the two tests with no obvious diurnal activity being observed. There were. however, minor changes occurring on the Servomex trace between 1900 - 0500 suggesting that a differing pattern of respiration was occurring at this time. In the third test the lobster died. On opening the chamber a noxious odour was present, along with a small amount of yellow, black non-viscous liquid. One lobster was healthy on revival from the chamber and recovered

well on return to seawater, the other had thrown one leg and was stressed. On re-examination of the metabolic rate graph, an unexplained increase in activity had occurred between 0900 and 1200 hrs. It is summised that someone had opened the incubator door and thereby caused stress to the lobster. This was an interesting result. Variability of condition of lobsters to handle 25°C could either be due to a better capacity for some lobsters to handle aerial exposure at 25°C for 24 hrs than others and/or a result of handling prior to induction of animal into test chamber.

In summary, the experimentation showed that the lower temperature of 10°C decreases respiration rate and produces healthy lobsters in good condition after 24 hours. Temperatures above 20°C lead to increases in respiration rate and produced lobsters in poorer condition after 24 hours. Exposure to temperatures of 25°C and above, led to some deaths after 24 hours.

Results using the experimentation equipment and experimental procedure, suggested that they may prove to be useful in the study of stress and stressors in the future. It is suggested that this be considered regarding further work and that this pilot study be repeated.

Results clearly illustrated that every effort to maintain a temperature below 10°C during transport of rock lobsters is worthwhile in terms of production of healthy live animals on arrival at export destinations.

7.5. References

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