Reducing Post-Capture Mortality When Storing Tropical Rock Lobsters For Live Export

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SUMMARY

For export of live ornate rock lobsters, *Panulirus ornatus,* from north Queensland, divers catch the lobsters by hand and keep them in small tanks on dories before draining the tanks and returning at speed to a mother ship which has a larger storage tank. However, sometimes the lobsters are too weak to export when the vessel returns to port to pack the consignment. In order to investigate possible causes of this problem we measured oxygen levels in the dory tanks and studied the physiological state of lobsters stored in a tank on the mother ship by measuring the concentrations of lactate, glucose, and ammonia concentration in the blood.

On the whole, lobsters reached the mother ship in a healthy state though capturing them by hand caused some injury to the lobsters and some further physical damage and cannibalism occurred while the lobsters were crowded in the catching bag. Oxygen levels were normally acceptable in the dory tank water, but fell rapidly below 50% saturation while flow was stopped and the dory tank was draining. The concentration of lactate in the blood of lobsters arriving from the dory was 16.4 ± 5.7mmol/L (n=9). Lactate is a waste product that accumulates when tissues are deprived of oxygen, and this level is surprisingly high in relation to reports of lactate levels in other commercially harvested crustaceans. The lactate level fell while the lobsters were stored on the mother ship indicating that they were recovering in the storage tank.

Conditions in the dory tank may contribute to the oxygen shortage implied by the high lactate concentration. It may be that lobsters usually tolerate these marginal conditions, but at certain times they are possibly more vulnerable, explaining the reported episodes of weakened lobsters. Ideally the lobsters should be stored in aerated seawater at all times and the fishery should move toward adopting, as much as practical, the Australian Rock Lobster Code of Practice. In the interim, improved water circulation and a design that allows rapid and complete draining would stop lobsters from suffocating in puddles of oxygen-poor water.

BACKGROUND

The lobster fishery in Torres Strait, based on the tropical rock lobster *Panulirus ornatus*, is modest in comparison to the industries based on the western and southern rock lobsters. A major source of income for Torres Strait Islanders, the annual catch in 1993 was 190 tonnes, with a reputed commercial value of $4.5 million (Pitcher and McLoughlin, 1994).

The Torres Strait lobster fishery has lagged behind while other lobster fisheries in Australia have made the shift to live marketing. Recently, the premium paid for live tropical lobsters in places like Hong Kong has stimulated increased effort in the export of live lobsters. The lobsters can be caught by hand (rather than spearing them) and so long as the lobsters are graded for strength prior to shipping this species appears to be just as tolerant of dry transport by air-freight as are other species of spiny or rock lobster (Rahman and Srikirishnadhas, 1994; Prescott, 1980).

NEED

Sometimes a relatively large portion of the catch (up to 15%) has to be rejected prior to packing for export. Some of these rejected lobsters have been physically injured on capture or even cannibalised by other lobsters. It is difficult to obtain a clear idea of the relative proportions of lobsters rejected for these different reasons without undertaking a comprehensive survey of several vessels, particularly since the episodes themselves appear sporadic and unpredictable. However, one reason for this problem is understandable. The fishery until recently harvested lobsters for tailing. Experience and practices that served that market well may not completely match with the more exacting requirements of handling live lobsters.

The ability to reduce the wastage of lobsters is limited by our poor understanding of the causes of these deaths. We cannot rely entirely upon guidelines such as the Rock Lobster Code of Practice because of the unique characteristics of the tropical lobster fishery. A survey of lobsters in captivity and the conditions under which they are stored will allow us to rule out well characterised problems such as poor water quality while at the same time providing information about physiological and pathological changes in the lobsters which will allow us to interpret the effects of changing handling methods.

OBJECTIVES

1. To observe and comment upon current practices for harvesting and storing tropical rock lobsters prior to export
2. To use these observations to propose changes to the handling regime, and conduct an experiment to assess the outcome of these changes in terms of lobster survival
3. To use the information gained from this experiment to recommend changes in the current handling practices, with the aim of reducing mortality of tropical rock lobsters during storage prior to export

METHODS

Outline of methods proposed

This project was planned to run in two stages, with field observations to be made during two trips to Torres Strait.

First field trip

The first trip involved observing current harvesting and storage methods. This would allow us to make recommendations about possible improvements in handling the lobsters from capture, while they were accumulated on board small boats and then transferred to the mother ship. At this time, we also proposed that we could plan an experiment where different handling methods will be compared in the second field trip.

Water quality measurements were to be made on the mother ship and dories using hand held temperature and oxygen meters. It was also expected that blood samples and tissue samples (for histology) will also be taken from 10 lobsters on unloading from the mother ship. These samples were to be taken back to the Centre for Food Technology and analysed for a number of known stress indicators. However, some logistical issues had to be overcome before samples could be taken and reliably returned to the laboratory.

Second field trip

The second field trip aimed to assess the results of changing the handling techniques on the survival and physiological condition of the lobsters. This work was conducted on a live lobster boat and a lobster dory fishing at Beka and Numa reefs (9°45'S 142°22'E and 9°40'S 142°20'E respectively) in central Torres Strait in June 1996. It was primarily intended to achieve the following aims...

(a) Continuously monitor changes in oxygen levels occurred in the holding tank on a dory during a days fishing using a data logging oxygen sensor

(b) Obtain blood samples from lobsters arriving on the mother ship and at different times following recovery. It was clear from the previous trip that it would not be practical to sample lobsters on the dories.

(c) Ascertain if there was a benefit from storing the lobsters in baskets on mother ship.

However, the vessel did not catch enough lobsters to address the last aim. We were however able to achieve the first and second aims, monitor oxygen levels in the dory (a) but only enough lobsters were caught to sample on arrival and during recovery on the mother ship (b). The planned basket experiment was called off after discussion with the applicant, whose preliminary tests suggested that baskets were inappropriate. This point was discussed with other fishers during the extension visit, and from their experience they were also loath to use anything that lobsters could grip onto.

Oxygen levels in dory tanks

Dissolved oxygen level in the water leaving the dory tanks was monitored using a DO 300 submersible oxygen sensor modified with a rapid response time membrane (Greenspan P/L Warwick). The sensor was placed inside the tank so that the membrane was adjacent to the outlet, ensuring water flow across the sensor membrane. It remained in place recording oxygen levels and temperature during a day's fishing operations.

Blood samples

Groups of nine lobsters had blood samples (about 1.5 ml) taken from them at different times after their arrival on the mother ship. As the catching pattern of each dory trip differed, this source of variation was distributed between sampling times. Therefore, after each trip, nine healthy lobsters were taken at random and three were sampled immediately, and each remaining group of 3 lobsters was submerged and their blood sampled after either 1, 3 or 9 hours recovery had elapsed. This continued until nine lobsters had been sampled in each time category.

Blood was taken (about 1.5 ml) from the fluid space (or sinus) around the heart using 2 ml plastic syringes and 25g hypodermic needles (38 mm long) and kept ice-cold to retard clotting. Access to the space was made via the thin membrane at the rear of the carapace ('head'). Lobsters were only sampled once.

A small sample (0.7 ml) of the blood was added to an equal volume of ice-cold 0.6 mol per litre perchloric acid to precipitate proteins as a fibrous white material. The sample extracts and remaining blood were frozen in small plastic containers in the mother ship's freezer and air-transported back to Brisbane and then stored at -70°C until analysis. Extracted samples were centrifuged and the clear liquid drawn off and its pH brought back toward neutrality (pH= 7) by addition of a volume, determined in preliminary laboratory work, of 3 mol per litre potassium hydroxide.The neutralised extracts were analysed for lactate and glucose using Boehringer Mannheim kits 139 084 and 716 251 respectively.

Ammonia concentration in frozen blood was determined by the Berthelot reaction (Sigma Diagnostics procedure no. 640) after thawing to 0°C. Blood ion concentration was then determined in the thawed blood samples. These were placed in a refrigerator and allowed to coagulate overnight. Then the clot in each was broken up using a clean stirring rod and the vials centrifuged for 30 min to produce a liquid which would no longer clot (serum) (Stewart et al., 1966). Magnesium and calcium concentration in this liquid was determined using the Calgamite method and the Arsenazo III method respectively (Trace Scientific P/L). The potassium concentration was determined by flame atomic absorption spectroscopy.

The T=0 sample of lobsters arriving on the FV Dolphin were tailed and then the 'head' was dissected to obtain samples for histological study to provide some feedback on the condition of lobsters arriving on the vessel. The following tissues were obtained; a piece of lateral abdominal muscle still attached to the thorax following tailing, the heart, the tip of the posterior lobe of the hepatopancreas, an arthrobranch of the third walking leg and the main lobe of the labyrinth of the antennal gland or 'kidney'. These samples were stored in Davidson's Fixative for transport back to the laboratory where they were trimmed and placed in histological cassettes in 80% ethanol prior to staining with H&E, mounting and sectioning.

DETAILED RESULTS

Current practices for harvesting and storing tropical rock lobsters

In addition to the hundreds of dinghies operating from island communities, there are several 'freezer' boats based in the straits. These act as mother ships to accompanying dories (Figure 1) and fish in the deeper waters not accessed by the islanders. Several of these boats operate as live lobster boats and are outfitted with on-board storage tanks for holding the catch during the 4-5 days that the boats stays at sea.

Catching from dories using hookah gear

Unlike many other rock lobsters, ornate rock lobsters are not caught in pots. Divers, either diving freely in shallow water or in the deeper waters using hookah gear, originally impaled the lobsters using short hand-spears. This capture method and the geographical isolation of the fishery means that much of the landed catch is still marketed as frozen "tails." However, for the live trade, the lobsters can be caught by hand, stored in a net bag with the other lobsters caught on that dive and then brought back to the dory.

Figure 1. An example of a hookah-equipped dory.

While the diver is below the surface attached by the "hookah" line, the driver of the dinghy has to follow the diver's bubbles, negotiate the current, the waves and swell. No direct observations of lobster behaviour underwater were made. The divers description of the lobster's reaction to capture suggests that at first the lobsters flip about in the net bag attempting to escape. But they soon settle down, and it is likely that they begin to recover from any exhaustion caused by capture. Some of them are comfortable enough to make a meal of other lobsters in the bag!

At the depths that the divers operate at they have a limited dive time. Of course, they seldom stay down for one long dive, instead surfacing after 30 to 45 minutes to exchange a bag of lobsters for an empty bag, or if the catch is small, to move the dinghy to another site. This means that lobsters are only confined in a bag for up to the maximum duration of individual dives.

The lobsters are relatively inactive when they arrive on the dory. Perhaps they are disoriented and/or blinded by being pulled from the water into bright sunlight. At this stage, on the boats we saw, some lobsters had managed to tangle their tails through the mesh, suggesting that the mesh used for the diver's bags was too wide. A few lobsters are already injured at this stage, with legs or antennal "whips" missing. This may be to some extent unavoidable due to the handling required to catch them- but perhaps struggling in the bag also contributes.

The advantage of using dories is that the mother ship can anchor in lee of a reef and the dories and divers supplying it can then speedily fan out over a large area of ocean using GPS equipment to visit particular features on the sea floor. The main problem, however, with using small dories is that the lobsters must be kept alive on a small dinghy for an hour or more before the dinghy returns them to the tank on the mother ship.

The design of the tanks vary considerably from dory to dory (Figure 2). Some tanks are anchored to the deck and filled using bilge pumps and the overflow runs passively via a drain back into the ocean. Presently, there do not appear to be many dories with tanks built into the deck below the water line. Either way, water can surge and slop about inside the tank, particularly in rough seas. A tank with smooth walls gives the lobsters nothing to grip onto to resist the buffeting of the water. One solution to this problem might be to add texture to the inner surface of the tank walls. The lobsters could then hold onto the wall. Using baskets in the dory tank does not seem to be practical, because the lobsters grip them too well.

Figure 2. Lobsters being removed from a dory tank prior to weighing onto the mother ship

Lobsters put into the dory tank often flap immediately when in contact with water again- an obvious attempt to "escape" from threat. These tanks should be shaded to avoid direct sunlight and have to provide the lobsters with environmental conditions that allow them to recover from the stresses imposed on them by capture and handling. The water flow into the tank should be adequate to supply the lobsters with all the oxygen they need. Disturbed lobsters have a high demand for oxygen, (Nimura and Inoue, 1969; Crear and Forteath, 1997a). If you look at the specifications on paper, bilge pumps provide sufficient water flow to meet this demand, but in practise that flow has to actually reach the lobsters. We used oxygen sensors to measure the oxygen levels in tanks on two dories and found that the levels were sometimes not as high as they should be.

Tank designs, such as the concept illustrated in Figure 3 should particularly address the "dead spaces" that can develop in the corners of a tank crowded with lobsters. Of course fishers could also use the hookah gear itself to aerate the tank water during fishing operations.

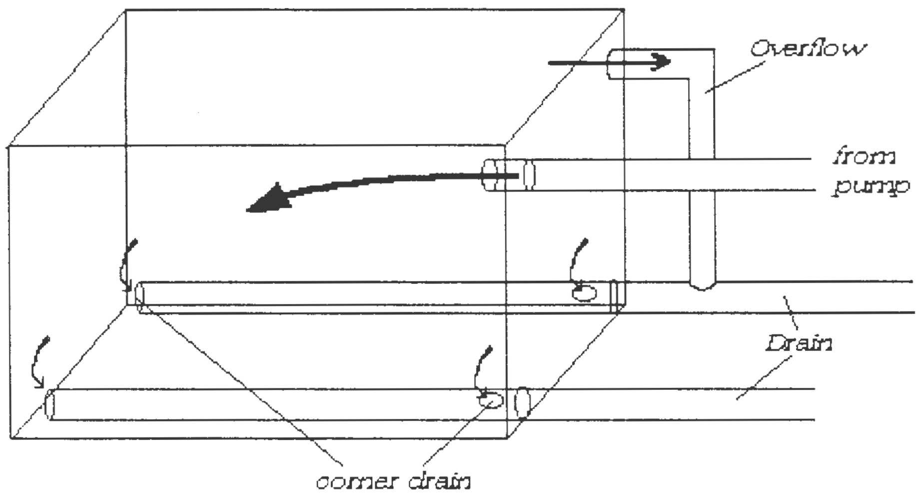

Figure 3. Diagrammatic concept for a tank located on the deck of a catching dory. Corner drains prevent dead spots developing by drawing water from amongst lobsters wedged into corners of the tank, and also allow the tank to drain completely when the pump is turned off. Not to scale.

The tanks are routinely drained for short periods when the dory is travelling at speed, either from dive site to dive site or when returning to the mother ship. With a tank located above sea level, you can simply turn off the pump and allow the water to drain out. While keeping the lobsters in air for even a few minutes may stress them, they are not completely starved of oxygen, the most immediate problem may be that lobsters in the bottom of the pile will suffocate in the water if the tank does not drain completely.

For example, at the temperatures typical of the Straits, 80 litres of water in a live well only has 360 ml of oxygen gas in it. If you put 20 kg of lobsters in that tank and stop water flowing into the tank then that amount of oxygen is only good for about five minutes before the lobsters have exhausted most of the available oxygen (Appendix 1). Now consider the situation of lobsters submerged in a partially drained wet well during an eight minute long journey between dive sites and you begin to see how marginal the performance of "straight forward" live wells may be.

During the second field trip (below), we measured the oxygen level in one dory tank during a days fishing operations and showed that there were often precipitous falls in oxygen level as the boat moved from dive site to site. And physiological observations of the lobsters arriving on the mother ship confirmed that they were being effected by the conditions on the dory.

Similar rapid falls in oxygen level are also reported in tanks used to keep western rock lobsters, *Panulirus cygnus*, on lobster fishing boats (Crear and Forteath, 1997b). The tropical lobster fishery could well profit from experience gained in this other fishery since the deck tanks used on some lobster boats in Western Australia are similar to those used on dories in the Torres Strait fishery. WA lobster boats using Nally tubs, such as the example in Figure 4, attach them to a manifold on a deck hose receiving water from a pump driven by the vessel's engine. The speed of the motor determines whether the lobsters receive enough water, particularly when the motor is idling while pots are being hauled to the surface (Crear and Forteath, 1997b). To overcome dead-spots in the tubs, it is recommended that the water enter the base of the tub and be distributed as evenly as possible across the floor of the tub using a spreader pipe. The water is then allowed to rise through the lobsters and overflow onto the deck. This design is simple to implement, but of course, in the context of a small tropical lobster dory, this set up would leave the dory awash with water, though it cannot be too difficult to devise something that channels the overflow back to the ocean.

Figure 4. An example of a deck tank on a western rock lobster fishing boat. A datalogging sensor is placed in the tub, recording oxygen level

Another bin system is used on some western rock lobster boats where water enters the top part of the bin and either overflows or leaves via holes drilled into the bottom corners of the tub. This pattern is similar to the concept for a tropical lobster dory tank shown in Figure 3. Problems envisaged with holding western rock lobsters in a top-entry bin with narrow drain holes in the bottom corners are firstly that there is a lot of wasted overflow, secondly, objects (like thrown legs for example) might block a fine hole and cause a 'dead spot' and thirdly that if the flow rate is too low, the tank will drain, leaving the lobsters high and dry (Crear and Forteath, 1997b).

But of course, this last 'problem' is actually standard practice when using dories in Torres Strait, because of the equally serious problem caused by surge in a speeding dinghy. The trade off being made here reflects the degree to which handling methods in this fishery are at odds with those of other lobster fisheries. Nevertheless, rock lobsters really ought to remain submerged in aerated seawater from the very moment of capture. In the long term, the tropical lobster fishery may have to adjust its methods of capture and handling so that they are more in tune with 'best practice' methods, namely, the submerged storage of the product.

Storage on the mother ship

It is worth noting that for all their apparent or potential faults, the dory tanks usually deliver lobsters to the mother ships that are apparently healthy. The arriving catch is weighed on board the boat in a lug basket and then graded for vigour and physical damage (Figure 5). Even after the brief journey back to the mother ship, some lobsters arrive in a weak or "sick" state, with a limp abdomen (tail) and legs and with evidence of swelling out of the loose membrane joining the tail and head of the lobster. These lobsters and the soft (post-moult) lobsters go into a "sick" tank on the back deck, while the vigorous lobsters are put into the live well, where they swim immediately from sight with flaps of their powerful tail. Most "sick" lobsters are expected to recover and along with the soft lobsters that may only take a few days to harden up, join the rest of the catch in the main tank.

Figure 5. Grading product prior to placing it in the mother ships storage tank

The storage tank present below deck on the mother ship that we observed was quite large, and easily able to accommodate catches of a couple of hundred kilograms gathered over a 4-5 day cruise. The tank was originally built for keeping live coral trout. Water is pumped in through a submerged spreader bar at the stern-ward upper end of the tank and either overflowed through the hatch or was pumped out via the ventral outlet. Dissolved oxygen levels in the tank were high and it appeared that the quantity in the tank at the time was not limiting (less than 200 kg, considered to be a low catch). However, if a large amount of lobsters were put in the tank it is clear that flow through the stacked lobsters would be reduced and low oxygen levels could develop.

For simple tanks of this nature, we recommend adding a removable slatted false floor so that the ventral draining pump draws water through the lobsters. Lobsters may of course cling too well to this for it to be practical. Alternatively, rather than adding the water at only one wall of the tank, the intake could be extended as a manifold so that water enters the tank at a number of points, to remove any dead spots from the tank and to better distribute the flow of new water amongst the lobsters.

Oxygen levels in dory tanks and physiological changes during recovery from capture

Introduction

Since preliminary observations suggested that the periods of poor circulation in the dory tanks were brief it became necessary to demonstrate not just that the oxygen level falls low, but to also understand what the consequences of this might be for the lobsters.

There is little physiological information on this species other than a study of the physiological deterioration in lobsters during the breeding migration (Trendall and Prescott, 1989). However, there is some comparative physiological data available from other lobsters and crabs during live transport and handling (Vermeer, 1987; DeFur et al., 1988; Spicer et al., 1990; Whiteley and Taylor, 1992).

Since lobsters are valuable, we primarily wish to obtain information about the animals state from a sample of its blood and secondly from its internal organs in the less valuable 'head' or carapace. In order to understand why we measured the things we did, it is helpful to have a brief guided tour of a lobster (Figure 6).

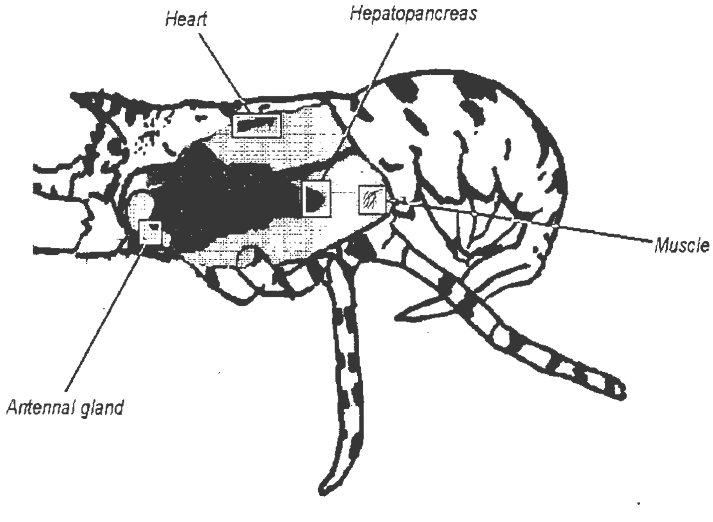

Figure 6. Location where tissue samples were taken within the carapace or 'head'

From the mouth, behind that impressive pair of jaws or mandibles, food passes into a complex stomach for filtering and grinding the meal. The broken down food passes through a short tubular mid-gut and any undigested material carries through into the hind-gut which, as the 'vein,' carries faeces to the anus at the tip of the tail. Branching off from the mid-gut soon after it leaves the stomach is a large lumpy brown-yellow organ called the mid-gut gland or hepatopancreas. This organ, a closely packed mass of tiny tubes, is not only used to help digestion and absorption of nutrients, it also acts as an important store of food reserves which can be released into the circulating blood.

The rock lobster's heart lies within the 'head', above the gut, close to the junction of the 'head' with the abdomen or 'tail.' The heart pumps the transparent blood through the animal's body via a radiating system of arteries. The blood returns through broader passages or 'sinuses,' first to the feathery gills under the protective curve of the carapace, where the blood picks up oxygen and loses the carbon dioxide and from thence to the heart and so forth. When lobster blood contains oxygen it acquires a grey-blue tint due to a special protein it contains that carries the oxygen.

When a lobster runs short of oxygen, it cannot metabolise its food and energy reserves properly and instead of converting it to gaseous carbon dioxide, the conversion process is incomplete and a potentially harmful waste product called lactic acid accumulates in its tissues and blood. Measuring the amount of lactic acid in the lobster's blood thus tells us whether or not it has been deprived of oxygen. Also, stressed or disturbed lobsters are reported to have high levels of glucose (a sugar) and low levels of ammonia in their blood, so it is also important to measure these compounds.

Approximately one third of a lobster's wet weight is its blood. The salts or ions in the blood of lobsters are generally present in the same amounts as occur in the surrounding seawater (Dall, 1974b). However, despite the lobsters inability to regulate the sodium or chloride level in their blood, they resemble other crustaceans in controlling the levels of certain physiologically important ions in the blood independently of the levels in the environment. Stressed lobsters are expected to show disturbances in the levels of these ions. Calcium levels in the blood change when lobsters moult and also when they experience internal acidity (such as accompanies production of lactic acid). Rises in blood magnesium level accompany moulting, commercial shipment or oxygen deprivation in lobsters and crabs (Albert and Ellington, 1985; Mercaldo Allen, 1991; Whiteley and Taylor, 1992).The levels of potassium and magnesium in the blood are not controlled by movements of ions across the gills, but instead are regulated by excretion via other organs and particularly the antennal gland, a pale organ adjacent to the base of the lobster's 'horns' or antenna. This organ filters blood (much like a kidney) and plays an important role in blood volume regulation, (Malley, 1977).

Lobsters are said by the fishers to be 'stressed' when the thin membrane joining the underside of the tail to the head appears distended. Further, weak or moribund lobsters are rejected because they are unable to lift their tails. Since these symptoms may also reflect physical changes to tissues, in addition to taking blood samples, we removed small samples of gill, tail muscle and other important internal organs (such as the heart, the hepatopancreas and antennal gland) from healthy lobsters and preserved them for microscopic examination. This was done to collect baseline information about tissue structures in healthy lobsters with which to compare these structures in moribund lobsters.

Since in this study we suspect that conditions in the dory tanks may stress the lobsters, we measured oxygen levels in the dory tanks and took haemolymph samples from lobsters arriving on the mother ship and following different periods of recovery. In order to compare the physiological condition of the lobsters with other data on captive lobsters and crabs, the samples were analysed for parameters known to respond to capture and handling, namely lactate, glucose, ammonia and blood ions (Vermeer, 1987; DeFur et al., 1988; Spicer et al., 1990; Whiteley and Taylor, 1992; Hunter and Uglow, 1993), as well as histological sections of important tissues.

Oxygen level in the dory tank

The dissolved oxygen levels in the storage tank on the dory were generally good, except for brief periods when the oxygen level fell precipitously when seawater stopped entering the tank (Figure 7).

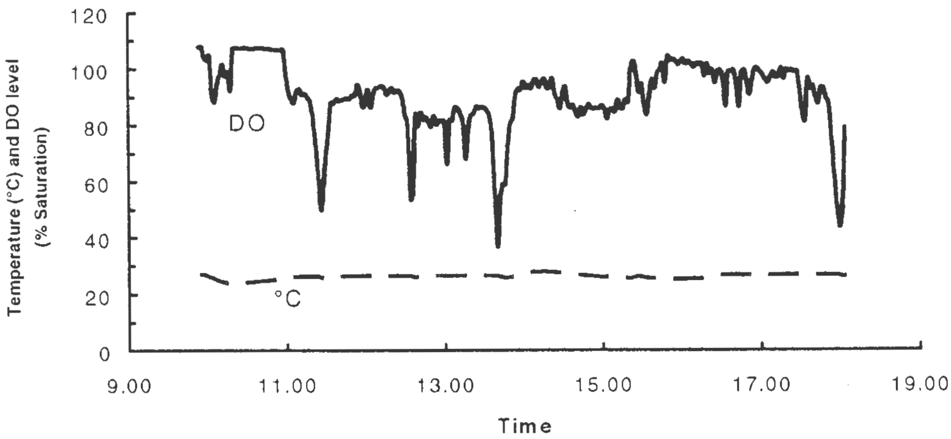

Figure 7. Record of dissolved oxygen and temperature in a dory tank during a day of fishing.

Lactate and glucose

Lobsters arriving on the mother ship had a lactate concentration of 16.4±5.7 mmol/L, (mean±SD, n=9) in their blood. Lactate concentration decreased while the lobsters were stored on the mother ship though the wide variation between lobsters early during storage makes it difficult to test the statistical significance of this fall (Table 1). The concentration of glucose in the blood of *P. ornatus* arriving on the mother ship was 1.8±0.7 mmol/L. The level of glucose in blood of lobsters sampled after 1 hour storage was significantly higher ($P<0.001$) than that of lobsters sampled on arrival or after longer periods of storage. There was considerable variation in both parameters. Glucose concentration was not correlated with lactate concentration ($r^2 = 0.25$). One lobster sampled 9 hours after being submerged on the mother ship had a glucose level of 3.1 mmol/L, outside the range obtained from the other eight lobsters (0.5 to 1.5 mmol/L).

Total Ammonia

No significant change in ammonia concentration occurred for the range of storage periods examined.

Table 1 Blood chemistry of tropical rock lobsters, *Panulirus ornatus* stored on a mother ship for up to 9 hours after arriving from a catching dory. (Concentrations are mean ±SD, in units of mmol L^{-1} Means with different letters against them are significantly different at 5%)

	Hours stored on mother ship			
	Arrival	1	3	9
no. of lobsters	9	9	9	9
Lactate	16.4±5.70	15.6±5.49	8.9±5.98	1.0±0.78
Glucose	1.8±0.86a	2.9±0.67b	2.3±0.53ab	1.3±0.76a
Ammonia	1.2±0.27	1.3±0.14	1.3±0.16	1.2±0.16

Serum electrolytes

The concentrations of all three ions analysed increased while the lobsters were stored on the mother ship (Table 2.). Magnesium levels where significantly higher after 1 hour storage ($P<0.05$) whereas lobsters sampled nine hours after arrival had significantly elevated potassium levels ($P<0.05$). Calcium levels in lobsters arriving on the mother ship were relatively uniform and increased variably from this in the stored lobsters (Table 2).

Table 2. Electrolytes in serum of tropical rock lobsters, *Panulirus ornatus* stored on a mother ship for up to 9 hours after arriving from a catching dory. (Concentrations are mean ±SD, in units of mmol L^{-1} Means with different letters against them are significantly different at 5%)

	Hours stored on mother ship			
	Arrival	1	3	9
no. of lobsters	9	9	9	9
Calcium	14.2±1.58	25.9±6.39	27.4±7.08	27.8±3.96
Magnesium	8.7±1.23a	14.5±3.50b	14.3±3.77b	13.1±1.57b
Potassium	8.7±1.65a	10.8±3.40b	10.5±4.12b	17.1±3.60b

Histology

There was no histological damage evident in any of the haematoxylin and eosin stained sections taken from the t=0 lobsters. The heart and abdominal muscle appeared normal and there was no evidence of damage to the gills, antennal gland or hepatopancreas.

Two interesting features were noticed. Firstly, brown crystals were found in the tubules of the antennal gland in one lobster (male, 100mm OCL) and the crystal photographed in Figure 8 was large enough to be visible to the unaided eye.

Secondly, there was variation in the state of the hepatopancreas amongst the lobsters (Figure 9). In some lobsters the walls of the tubules were thick and finely partitioned and the fluid space between the tubules contained darkly stained ('eosinophilic') pink cells that are apparently the 'reserve inclusion cells' of Johnson (1980). In other lobsters, the tubule walls were generally dominated by large bubble-like vacuoles (evidence of active secretion of materials into the lumen) and the densely-stained cells were absent from the spaces between the tubules.

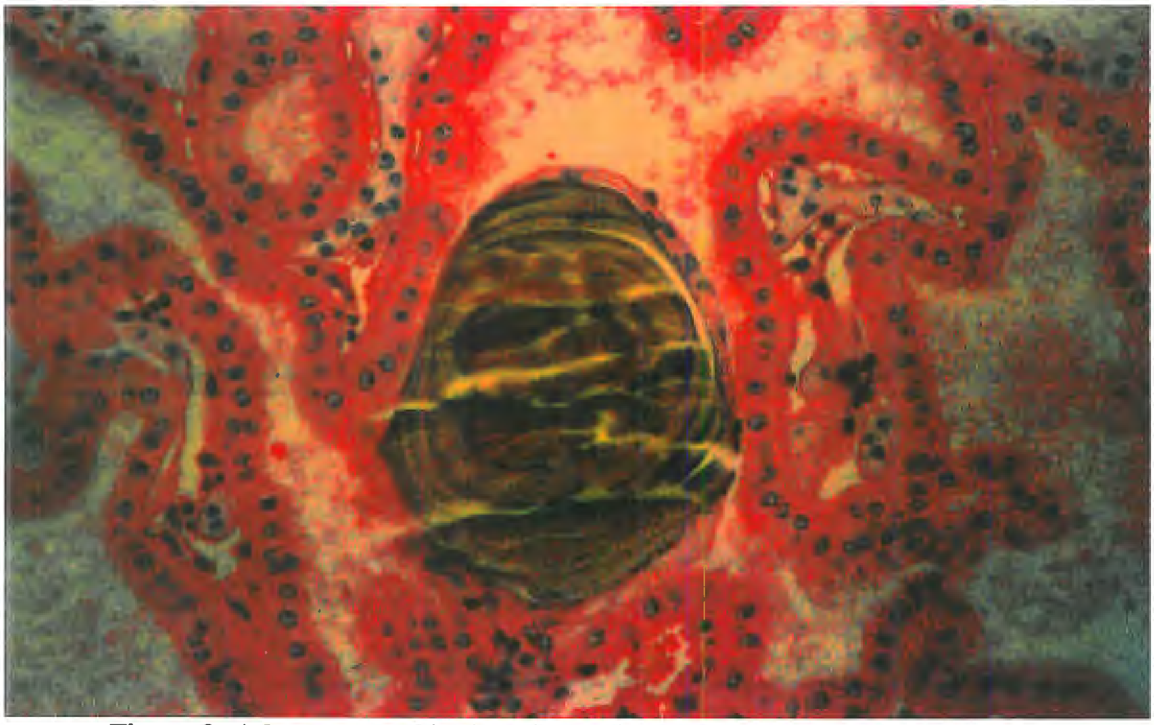

Figure 8. A large crystal in the labyrinth of a *P. ornatus* antennal gland.

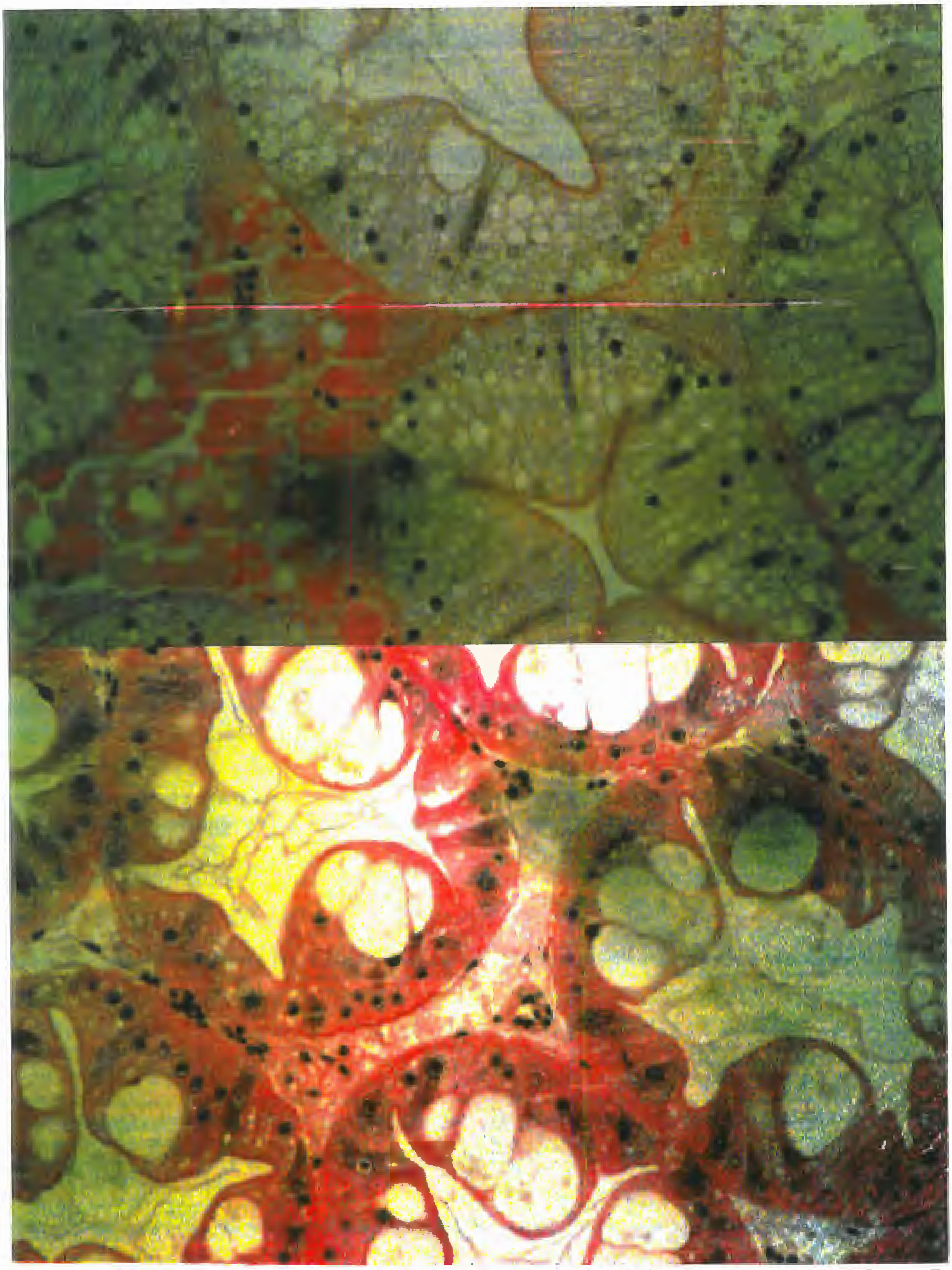

Figure 9. Histology of the hepatopancreas (digestive gland) in the ornate rock lobster *P. ornatus*.(a) Lobster with non-secretory tubules. (b) Lobster with secretory tubules. L= tubule lumen, RI= reserve inclusion cell, V= secretory vacuole

Discussion

The lobsters sampled in this study showed no symptoms of morbidity such as flaccid abdomen or legs. Yet, those lobsters arriving on the mother ship on average have very high levels of lactate in their blood, indicating that they are in a state of oxygen debt, which could be a result of a number of aspects of their prior handling, such as exercise (Field et al., 1991), emersion (Whiteley et al., 1990; Whiteley and Taylor, 1990), or aquatic hypoxia (Lowery and Tate, 1986).

The divers admit that the lobsters flap their abdomens when captured, when put in the net bag and they also tail-flap when placed in the dory tank. However, the levels of lactate found here seem excessive when compared with levels in blood of *P. argus* kept out of water for a much longer period (2 hours), (Vermeer, 1987) or levels in exercising crayfish (Phillips et al., 1977; Head and Baldwin, 1986). Thus, a combination of several factors may be involved.

While we cannot point out the exact cause of the lactate build up, it is clear that these disturbed lobsters will have a higher than normal respiration rate (Nimura and Inoue, 1969). Disturbed lobsters crowded into a small volume of static seawater at 25-30°C will exhaust the oxygen available more rapidly than resting, undisturbed lobsters would. Blood lactate concentration fell when lobsters were allowed to recover submerged on the mother ship. An oxygen debt is often repaid by heightened rate of oxygen consumption during lactate metabolism (Bridges and Brand, 1980).

The concentration of glucose in the blood of *P. ornatus* arriving on the mother ship was only slightly higher than reported for fed undisturbed western rock lobster *P. cygnus* in the laboratory (1.2 mmol/L), (Dall, 1974a). This finding is encouraging, if unexpected. Glucose level is recognised as a general indicator of stress in crustaceans and judging by this previous work on *P. cygnus*, considerably higher levels of glucose were expected in the blood of disturbed animals. However, baseline levels of glucose in wild lobsters are possibly lower than that in captive lobsters, judging from observations of Norway lobsters (*Nephrops norvegicus*) and American lobsters (*Homarus americanus*) (Telford, 1968; Spicer et al., 1990), so even these levels may indicate a degree of stress.

The apparent brief rise in glucose level in lobsters on the mother ship, is at least consistent with the idea that the lobsters are disturbed by handling. But some caution is required when interpreting this peak primarily as a 'stress' response. Perhaps lobsters are simply converting some lactate to glucose. And the higher level attained at 1 h could conceivably be the trailing shoulder of an even higher peak in glucose concentration that was missed by the sampling protocol.

Hypoxia and handling are reported to reduce the blood ammonia level in decapods, (Hagerman et al., 1990; Hunter and Uglow, 1993). However, the ammonia concentration in lobsters arriving on the mother ship was higher than the range reported from various crustaceans, (Hagerman et al., 1990) and higher than that reported from *P. argus* after 2 hours in air (Vermeer, 1987). Furthermore, the level in the blood did not change during the period of sampling, though clearly, information about ammonia excretion is required to interpret this.

There was considerable variation between lobsters in lactate and glucose concentration in the blood. This may be because the lobsters have been in captivity for different periods, because they have been stressed to different degrees or even because they show broad intrinsic variation. For example, a bag of lobsters brought onto the dory just before returning may not actually be submerged until the dory reaches the mother ship.

Despite the high levels of lactate in the lobsters arriving on the mother ship, the levels of calcium, magnesium and potassium ions in the blood of the newly caught tropical rock lobsters were close to that would be considered normal in other rock lobsters (Travis, 1955b; Dall, 1974b; Mercaldo Allen, 1991). But the levels of these ions increased to abnormal levels while the lobsters were apparently recovering on the mother ship. This may be a delayed response to the previous stress on the dory. The late rise in potassium level is cause for concern because resting lobsters normally tightly regulate the level of this ion, (Dall, 1974b). We need observations lobsters that are in captivity for longer periods to find out whether these elevated levels are sustained or whether the concentrations fall again.

Since tropical lobsters are caught by hand, a wider range of moult stages may be taken than by fishers using pots. Though not included in these samples, even soft, post-moult lobsters may be brought on board to harden up (if they aren't cannibalised in the diver's bag). Many of the parameters measured here, and particularly calcium level, will vary widely during the moult cycle (Travis, 1955b; Mercaldo Allen, 1991; Mangum, 1992). While the blood calcium level in lobsters received on the mother ship was relatively uniform (Table 2), histological sections of hepatopancreas from lobsters arriving on the mother ship showed that some lobsters have far fewer 'reserve cells' in the spaces between the tubules, a difference possibly associated with progress through the moult cycle (Travis, 1955a; Travis, 1957). As their name implies, these reserve cells store materials that can then be made available to physiological processes such as moulting. The loss of reserve cells from the spaces between the tubules may raise the water content of the hepatopancreas, a trend perhaps continued by the dramatic rise in water content observed in migrating lobsters (Trendall and Prescott, 1989).

The fine tubules of the hepatopancreas also varied in their structure. In some lobsters the wall showed large clear bubble-like vacuoles of secretory B-cells, while in other lobsters a sample from the same part of the hepatopancreas showed tubule walls that were more finely partitioned, in the manner of absorption cells (Travis, 1955a, 1957). The lack of secretory cells suggests that some of these captured lobsters are not currently feeding.

Variations in condition possibly influence the stress susceptibility of lobsters. Presently, other than grading lobsters for weakness, damage or soft-shell, the fishers and live processors handling tropical rock lobsters have no other simple methods of grading lobsters for condition. However, the condition of lobsters is related to their tissue mass or conversely, to the blood volume (Dall, 1975). Protein levels in the blood become concentrated or diluted as the blood volume shrinks or rises and the protein level (as refractive index) can be measured relatively easily on a boat or in a factory using a hand-held refractometer (Dall, 1975; Leavitt and Bayer, 1977). Judging from the variation in tissue sections observed in these lobsters, blood protein level could be an important parameter to measure in future studies of lobster harvesting.

This study shows that low oxygen tensions in the dory tank may contribute to the 'oxygen debt' implied by the lactate levels in lobsters arriving on the mother ship. While conditions in the tanks are probably adequate under most circumstances, it may be that they become marginal under circumstances when there are large catches and instances when the lobsters are more vulnerable to low oxygen stress, such as at particular stages of the moult cycle. The best option would be for the lobsters to remain submerged in flowing seawater. However, in the short term, improved water circulation and a design that allows rapid and complete draining would at least stop lobsters from suffocating in puddles of hypoxic water.

Extension visit

The project concluded with an extension visit by Dr Paterson to Thursday Island, where the findings of the research were discussed with local fishers. This visit was also an opportunity to discuss extension with the local office of AFMA, which manages the fishery and thus has an ongoing program of information extension.

The visit was timed to coincide with a meeting of local QCFO members on November 27th, just prior to the end of the October/November ban on hookah fishing for lobsters. This visit provided an excellent opportunity to discuss the findings and preliminary recommendations of the project with a wider group of people experienced in harvesting and handling tropical lobsters and thus obtain feedback on the practicality of some suggestions about the tanking of the lobsters.

Following the meeting, Dr Paterson gave a brief account of the study on the AFMA program on Torres Strait radio and also undertook to complete a section on lobster handling for inclusion in a handbook for lobster fishers being prepared by AFMA.

Information relating to the promotion of the visit, examples of the transparencies used in the talk and the draft of the section for the AFMA handbook are included in Appendix II.

BENEFITS

The primary benefit of this research is to reinforce the need for good handling practices in this fishery and to provide data on the condition of lobsters being harvested. While these observation was confined to one mother ship, it is likely that the general findings hold throughout the fishery- namely that efforts should be made to ensure effective levels of water circulation through dinghy tanks.

Fishers will differ in their approach to lobster handling and it is likely that those fishers who contributed to the field work and extension parts of this project are already aware of the issues involved in handling live product.

Publicising the benefits of better handling practices more widely amongst the fishery, for example through the extension article in Appendix II, will hopefully lead to an overall improvement handling practices, and widen the marketing options for the lobsters.

FURTHER DEVELOPMENT

- In general, tropical lobster harvesters should follow as much as practicable the guidelines for handling rock lobsters in the Australian Rock Lobster Code of Practice.
- Discussions with WAFIC could begin to develop a regional supplement to the Rock Lobster Code of Practice, using the information gained in the current project and in discussion with industry members, detailing guidelines specific to handling tropical rock lobsters (eg. Use of divers, storing lobsters on small dinghies etc).
- Attention should be given as a matter of priority to improving the design and performance of storage tanks on the catching dinghies to increase the margin of safety when lobsters are held submerged in water. These improvements are straight-forward in practical terms with outcomes in terms of reliable water quality and improved respiratory health of the lobsters. Tanks in existing dories should be modified to prevent lobsters suffocating in anoxic water in partially drained tanks. However, in the long term, a move should be made to storing lobsters in aerated seawater at all times.
- The storage tank on mother ship can probably also be improved, particularly by providing infrastructure or stacking baskets so that the lobsters don't all end up several layers deep

on the floor of the tank. However, the patchiness of catches mean that this and other mother ships probably have tanks with a holding capacity well in excess of the typical catch.

ACKNOWLEDGEMENTS

Special thanks to Lindsay and Linda Hill (Freshway Seafoods P/L) for their hospitality and assistance on the FV *Dolphin* as well as to Diane and Phil Hughes and other tropical lobster fishers for their hospitality. Alan McManus (QDPI Animal Research Institute) conducted the serum electrolyte determinations. Part of this work was presented as a poster to the Fifth International Conference and Workshop on Lobster Biology and Management, Queenstown, New Zealand, February 9th-14th and was published in the proceedings (Paterson, B.D., Grauf, S.G. and Smith, R.A. 1997. Hemolymph chemistry of tropical rock lobsters, *Panulirus ornatus* brought onto a mother ship from a catching dinghy in Torres Strait. Marine and Freshwater Research 48, 835-838).

LITERATURE CITED

Albert, J.L. and Ellington, W.R. (1985). Patterns and energy metabolism in the stone crab, *Menippe mercenaria*, during severe hypoxia and subsequent recovery. Journal of Experimental Zoology 234, 175-183.

Bridges, C.R. and Brand, A.R. (1980). The effect of hypoxia on oxygen consumption and blood lactate levels on some marine Crustacea. Comparative Biochemistry and Physiology 65A, 399-409.

Crear, B. and Forteath, N. (1997a). Maintaining rock lobsters in prime condition on board lobster boats- part 1. Professional Fisherman. March 1997: 24-26.

Crear, B. and Forteath, N. (1997b). Maintaining rock lobsters in prime condition on board lobster boats- part 2. Professional Fisherman. May 1997: 16-18.

Dall, W. (1974a). Indices of nutritional state in the western rock lobster, *Panulirus longipes* (Milne Edwards). I. Blood and tissue constituents and water content. Journal of Experimental Marine Biology and Ecology 16, 167-180.

Dall, W. (1974b). Osmotic and ionic regulation in the western rock lobster *Panulirus longipes*. Journal of Experimental Marine Biology and Ecology 15, 97-125.

Dall, W. (1975). Indices of nutritional state in the western rock lobster, *Panulirus longipes* (Milne Edwards). II. gastric fluid constituents. Journal of Experimental Marine Biology and Ecology 18, 1-18.

DeFur, P.L., Pease, A., Siebelink, A. and Elfers, S. (1988). Respiratory responses of blue crabs, *Callinectes sapidus*, to emersion. Comparative Biochemistry and Physiology 89A, 97-101.

Field, R.H., Taylor, A.C., Neil, D.M. and Chapman, C.J. (1991). Factors affecting swimming ability and its recovery in the Norway lobster (*Nephrops norvegicus*). Journal of the Marine Biology Association of the United Kingdom 71, 735-736.

Hagerman, L., Sondergaard, T., Hosie, D. and Uglow, R.F. (1990). Aspects of blood physiology and ammonia excretion in *Nephrops norvegicus* under hypoxia. Comparative Biochemistry and Physiology 97A, 51-55.

Head, G. and Baldwin, J. (1986). Energy metabolism and the fate of lactate during recovery from exercise in the Australian freshwater crayfish *Cherax destructor*. Australian Journal of Marine and Freshwater Research 37, 641-647.

Hunter, D.A. and Uglow, R.F. (1993). Handling-induced changes in haemolymph ammonia concentration and ammonia excretion rate of *Crangon crangon* (L.). Ophelia 38, 137-147.

Johnson, P.T. (1980). Histology of the Blue Crab, *Callinectes sapidus* : a Model for the Decapoda. Praeger Publishers, New York. 440pp.

Leavitt, D.F. and Bayer, R.C. (1977). A refractometric method for determining serum protein concentration in the American lobster. Aquaculture 12, 169-171.

Lowery, T.A. and Tate, L.G. (1986). Effect of hypoxia on hemolymph lactate and behaviour of the blue crab *Callinectes sapidus* Rathburn in the laboratory and field. Comparative Biochemistry and Physiology 85A, 689-692.

Malley, D.F. (1977). Salt and water balance of the spiny lobster, *Panulirus argus*: the role of the antennal gland. Journal of Experimental Biology 70, 221-230.

Mangum, C.P. (1992). Physiological aspects of molting in the blue crab *Callinectes sapidus*. American Zoologist 32, 459-469.

Mercaldo Allen, R. (1991). Changes in the blood chemistry of the American lobster, *Homarus americanus*, H. Milne Edwards, 1837, over the molt cycle. Journal of Shellfish Research 10, 147-156.

Nimura, Y. and Inoue, M. (1969). Oxygen uptake rate of the Japanese spiny lobster as related to the environmental oxygen concentration. Bulletin of the Japanese Society of Scientific Fisheries 35, 852-861.

Phillips, J.W., McKinney, R.J.W., Hird, F.J.R. and MacMillan, D.L. (1977). Lactic acid formation in crustaceans and the liver function of the midgut gland questioned. Comparative Biochemistry and Physiology 56B, 427-433.

Pitcher, R. and McLoughlin, R.K. (1994). Torres Strait lobster. In K. McLoughlin, K. Staples and M. Maliel, (Eds). Bureau of Rural Resources, Canberra, pp 19-24.

Prescott, J. (1980). A handbook for lobster fishermen of the tropical Pacific islands. South Pacific Commission, Noumea, New Caledonia

Rahman, K. and Srikirishnadhas, B. (1994). Packing of live lobsters- the Indian experience. INFOFISH International 94, 47-49.

Spicer, J.I., Hill, A.D., Taylor, A.C. and Strang, R.H.C. (1990). Effect of aerial exposure on concentrations of selected metabolites in blood of the Norway lobster *Nephrops norvegicus* (Crustacea: Nephropidae). Marine Biology 105, 129-135.

Stewart, J.E., Dingle, J.R. and Odense, P.H. (1966). Constituents of the hemolymph of the lobster *Homarus americanus* Milne Edwards. Canadian Journal of Biochemistry 44, 1447-1459.

Telford, M. (1968). The effects of stress on blood sugar composition of the lobster, *Homarus americanus*. Canadian Journal of Zoology 46, 819-826.

Travis, D.F. (1955a). The molting cycle of the spiny lobster, *Panulirus argus* Latrielle. II. Pre-ecdysial histological and histochemical changes in the hepatopancreas and integumental tissues. Biological Bulletin 108, 88-112.

Travis, D.F. (1955b). The molting cycle of the spiny lobster, *Panulirus argus* Latrielle. III. Physiological changes which occur in the blood and urine during the molting cycle. Biological Bulletin 109, 484-503.

Travis, D.F. (1957). The molting cycle of the spiny lobster, *Panulirus argus* Latrielle. IV. Post-ecdysial histological and histochemical changes in the hepatopancreas and integumental tissues. Biological Bulletin 113, 451-479.

Trendall, J.T. and Prescott, J. (1989). Severe physiological stress associated with the annual breeding emigration of *Panulirus ornatus* in the Torres Strait. Marine Ecology Progress Series 58, 29-39.

Vermeer, G.K. (1987). Effects of air exposure on desiccation rate, hemolymph chemistry, and escape behaviour of the spiny lobster, *Panulirus argus*. Fishery Bulletin 85, 45-51.

Whiteley, N.M., Al-Wassia, A.H. and Taylor, E.W. (1990). The effect of temperature, aerial exposure and disturbance on oxygen consumption in the lobster *Homarus gammarus* (L.). Marine Behavioural Physiology 17, 213-222.

Whiteley, N.M. and Taylor, E.W. (1990). The acid-base consequences of aerial exposure of the lobster, *Homarus gammarus*, at 10 and 20 °C. Journal of Thermal Biology 15, 47-56.

Whiteley, N.M. and Taylor, E.W. (1992). Oxygen and acid-base disturbances in the hemolymph of the lobster *Homarus gammarus* during commercial transport and storage. Journal of Crustacean Biology 12, 19-30.

APPENDIX I. CALCULATIONS

How much seawater flow does a recently caught lobster need?	
Oxygen level in tank inflow (from published tables)	**4.5 ml 0_2 / litre**
Estimated maximum lobster respiration rate (from literature values)	**150 ml 0_2 /kg/h**
Flow rate, per kilogram of lobster, required to satisfy this respiration rate	**33.3 litres/kg/h**

How quickly can lobsters exhuast the oxygen available in a static dinghy tank?	
Volume of dinghy tank	**80 litres**
Weight of lobsters	**20 kg**
Oxygen level in tank inflow (from published tables)	**4.5 ml 0_2 / litre**
Oxygen content of dinghy tank water (volume x oxygen level)	**360 ml 0_2**
Estimated maximum lobster respiration rate (from literature values)	**150 ml 0_2 /kg/h**
Estimated oxygen demand of lobsters in dinghy tank (weight of lobsters times the respiration rate of one kilo of lobsters)	**3000 ml 0_2 /h**
Time to exhaust oxygen in zero flow (oxygen content/oxygen demand and converted to minutes)	**7.2 minutes**

APPENDIX II. EXTENSION VISIT

(a) Promotion of the presentation in conjunction with local QCFO meeting in late November 1997
(b) Copies of transparencies used at presentation to fishermen
(c) Article written for AFMA lobster handbook

TORRES STRAIT COOPERATIVE SOCIETY LTD.

ANNUAL GENERAL MEETING

All members of the above Cooperative are hereby notified that their Annual General Meeting for 1997 will be held in the **Anglican Parish Hall at 10 am on Saturday 22/11/97.**

John A Majid
Manager

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PORT KENNEDY ASSOCIATION

The Administration Office
and the
Social Worker
are now situated in the new
Port Kennedy Community Hall

64-66 Douglas St.

FISHING MEETING

Thursday 27 November
9.00am
Pearls Building Conference Room

BRIAN PATERSON from **DPI** will address the meeting about
LIVE CRAYFISH STORAGE AND HANDLING

** Also on the agenda **
- *Minimum legal size for cray tails*
- *Boat replacement policy*
- *Sea rights*

1998 Diaries On Sale NOW at Torres News

A4 1 day to a page	$10.50
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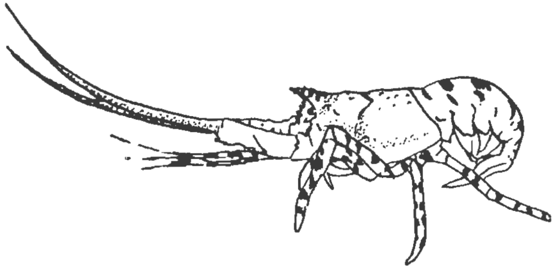

The Principles

- Handle crayfish carefully
  - keep damage to a minimum
- Keep them in air only briefly
  - they suffocate out of water
- Store them in seawater
  - well flowing, and circulating

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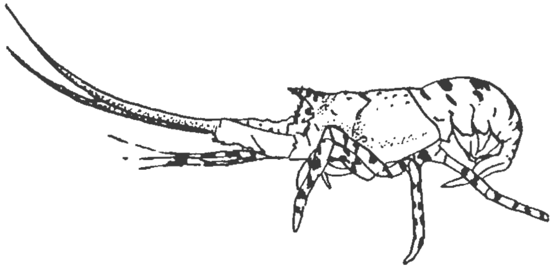
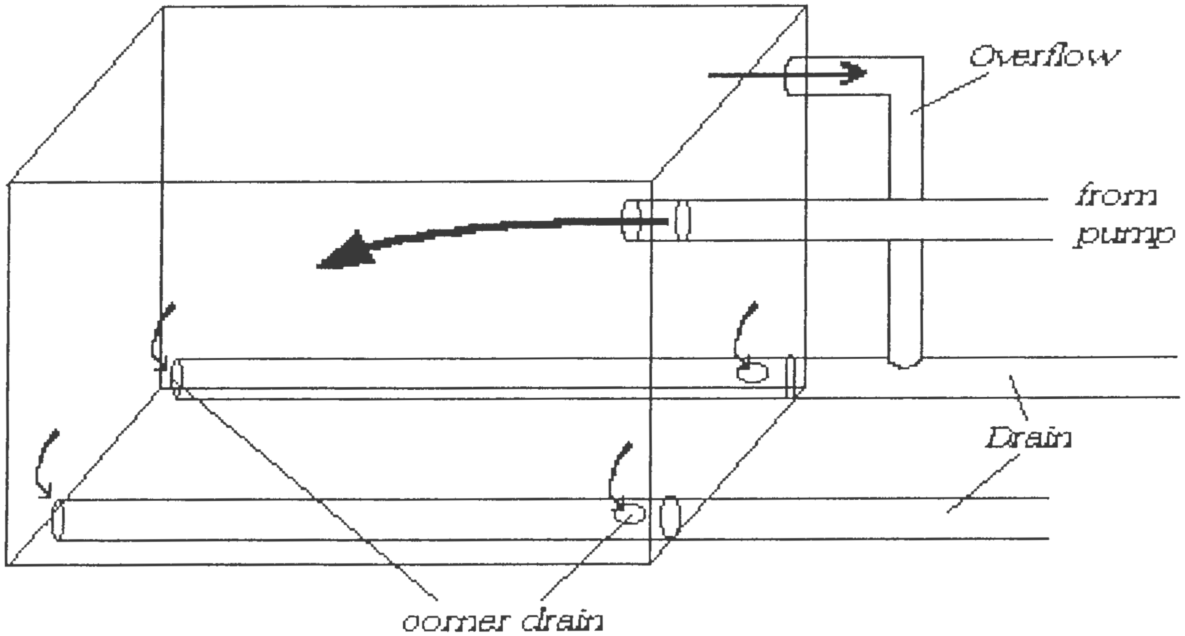
CENTRE FOR **FOOD TECHNOLOGY**



A dinghy tank



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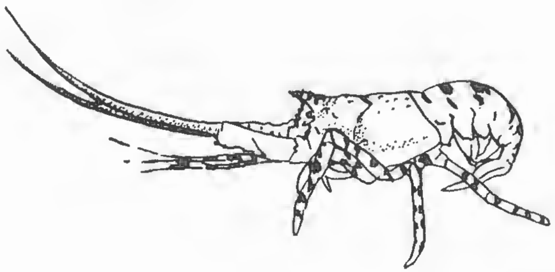
Other ideas...



CENTRE FOR **FOOD TECHNOLOGY**

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HANDLING LIVE CRAYFISH IN TORRES STRAIT

GETTING STARTED

Markets in South East Asia want living tropical crayfish because of their size and attractive colour. Fortunately, when it comes to handling for sale, tropical crayfish are relatively strong and able to survive the journey to market. All the same, you should make their journey to market as easy as possible. This should be simple to achieve, but remember that crayfish belong underwater and they are usually unable to live for long periods out of the ocean. Of course, aircraft can take crayfish out of the Straits and overseas, but that does not mean you can keep a crayfish alive in the baking sun.

When you are fishing, crayfish should be out of water as briefly as possible. After all, how long can you hold your breath for, underwater? Not long. When you get back to the surface after holding your breath, you take a nice deep breath. That is what a period in air is like for a crayfish. Of course, crayfish hold their 'breath' longer than people can. No one I know could hold their breath on the flight from TI to Cairns. Crayfish that have been in air need well flowing seawater when placed in a storage tank. This allows the crayfish to recover enough to put up with more handling on the way to market.

CATCHING CRAYFISH

The fishery for crayfish in Torres Strait initially produced frozen crayfish tails. Several 'freezer' boats and associated dinghies fitted with hookah gear work in the deeper waters of the Straits. Divers using hookah breathe air fed down a line from a compressor in the dinghy. As interest in live export has grown, several of these licences now operate as live crayfish boats and have storage tanks for holding the catch during the 4-5 days that the boat stays at sea. Fishers from the island communities dive unaided from dinghies to take crayfish from the relatively shallow waters of reefs but still account for most of the landed catch.

Divers harvest the crayfish using hand-spears or more recently for the live market, by hand alone. Visibility is important, so fishing usually occurs during neap tides when currents are slower and the water clearer. The crayfish boat can anchor in lee of a reef and the divers supplying it can efficiently cover a large area of ocean in their dinghies. This means, however, that crayfish must stay for hours on a small dinghy.

LIVE CRAYFISH DINGHIES

When the diver brings the catch in, the dinghy driver should take the crayfish carefully from the bag to avoid damaging them. Return any undersized animals, those with a tail length less than 100 mm, to the sea at this stage and put the others as soon as possible in flowing seawater in the dinghy tank. This keeps them out of the sun and wind. The inside walls of the tank should not be slippery because the crayfish will need a foot hold to withstand the water flow in the tank. Pump seawater into the tank, for example using a bilge pump, and see that the water circulates amongst the crayfish. The crayfish need high rates of water flow soon after capture to allow them to cope with the rough handling. Bilge pumps easily supply seawater at the levels of flow required for a typical dinghy catch but take care that the water flows between and not around the crayfish.

Drain the tank on the dinghy when travelling at speed between dive sites or when going back to the fishing boat. Design the tank carefully so that all water drains from it when flow stops. This stops the crayfish from being battered and injured by water splashing in the tank. In addition, crayfish trapped in any stagnant water remaining in the tank will have even more difficulty breathing than crayfish kept in air. Air supplies at least some of the oxygen gas that they need, while there might be no oxygen in that stagnant water.

The dinghies usually deliver crayfish alive to the fishing boat or shore, despite these short periods in air. However, some times crayfish may need all the help they can get. A better system would see that the crayfish stay in flowing seawater at all times- but this would require a re-think of the capture operation.

FISHING BOATS AND STORAGE TANKS

Operating a storage tank on a fishing boat is like operating at tank on shore. You pump water from the ocean, amongst the catch, and let it drain back into the sea. When the supply of good quality seawater is not reliable on shore, for example near a river or port, you should use a seawater recirculation system. These systems recycle the seawater by using special filters to dispose of the crayfish's wastes. When cooled below seawater temperature, recirculation systems are a good way of storing large numbers of crayfish, but they take more looking after than a simple pump system.

Grade the catch for strength and physical damage as it arrives from the dinghy. Some crayfish look weak when they arrive, their tail and legs are limp and the loose skin between their head and tail swells a bit. Keep these weak crayfish, and the crayfish with soft shells, away from the rest of the catch, which might attempt to eat them! You can do this using a smaller storage tank, a fenced off part of the main tank or simply a large tub or esky of seawater on the deck of the fishing boat. Put the lively, strong crayfish directly into the main storage tank. When they feel the water, they often swim immediately with flaps of their powerful tail. Recent handling has weakened the other crayfish. Let them get their strength back in the "sick tank" and if they have got better when looked at later on, they can join the rest of the catch in the main storage tank. The soft crayfish may take only a few days for their shells to harden up so until then, keep them away from the other, hungry crayfish.

The storage tank keeps more crayfish than a dinghy would carry, but has to do the same job. The seawater in the tank has to be like the ocean, allowing crayfish to breathe and do all the things that crayfish have to do. Water must move amongst the crowded crayfish without the tide or waves to stir it along. Pump seawater through the tank and amongst the crayfish fast enough so that they don't foul the water with their own wastes. Aim to pump more than 30 litres per hour for every kilogram of crayfish. This number assumes the crayfish just arrived and gives a good margin of safety for crayfish that have been in the tank for a day or more. Too much flow, without going completely over the top, is better than not enough. A tank of 100 kg of recently captured or transported crayfish needs at least 3000 litres of seawater every hour to supply them with oxygen.

Simply delivering the water to the tank at this rate is, of course, just the beginning. You've also got to make sure each crayfish gets its share. Crayfish on the bottom of a heap of other crayfish may find themselves in a dead spot, where the crowd of spiny bodies blocks water flow. Avoid this by not putting too many lobsters in the tank. Allowing crayfish to climb from the floor of the tank is another a simple way around this problem. Try putting plastic baskets in the tank, lying on their side.

The storage tank must satisfy the needs of the crayfish crowded inside it. Don't make them too comfortable, though. Lighting the tank at all times of the night and day would be a good idea. Crayfish feed in the dark.

PACKING AND SENDING THEM OFF

Transport crayfish when they've been kept in a storage tank for at least a day after capture. They recover from the effects of capture in this time. Don't pack any crayfish that seem weak and sluggish. Transport is stressful enough without sending crayfish that may not survive. Crayfish normally survive for several hours or more in air when you ship them, but there are several things keep in mind. The problems are less serious if the journey is short. A short journey involves sending crayfish between islands as apposed to flights to a seafood processor in Cairns who will again tank the crayfish and air-freight them later overseas.

Pack the crayfish into polystyrene foam boxes or something else that is also approved by airlines for the transport of dry crayfish. You can do a number of things to help the crayfish on their way. Believe it or not, while crayfish breathe best underwater, poking a few air-holes in the carton walls may not be such a bad idea. Crayfish can breathe slightly in air- and every little bit helps. They obviously cannot breathe as well in air as they can in water, so pack the crayfish in material that stops them from moving. This could be something as basic as newspaper of course but a crayfish exporter uses wood shavings or something similar. Pack the crayfish just tightly enough so that they cannot struggle or move inside the container. If they struggle while out of water they will want much more from the air than they can get.

High temperature is a serious problem during transport. Hot crayfish want more oxygen and can't be satisfied by breathing air. Crayfish will cope better if you cool them down, say by about five degrees Centigrade below the temperature of the sea they came from. They can be cooled prior to transport, for example in a tank equipped with cooling equipment or mix enough ice into a tank to cool it. A frozen bottle of water (up to 1 litre), wrapped in newspaper, can be added with the crayfish to stop the carton from warming too much, particularly in hot weather. Stop the crayfish drying out by keeping it damp inside the container.

CONTACT: Brian Paterson, Centre for Food Technology, Queensland Department of Primary Industries, 19 Hercules St Hamilton 4007. Phone 07 3406 8555 Fax 07 3406 8698. **This advice was developed following work in Torres Strait initiated by Mr Lindsay Hill, Freshway Seafoods P/L, in a project supported by the National Seafood Centre (Project 92/125.27). The assistance and hospitality of Phil and Di Hughes and other QCFO members on Thursday Island is greatly appreciated.**