REPORT ON THE SOUTH PACIFIC COMMISSION LOBSTER PROJECT IN SOLOMON ISLANDS

by

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ABSTRACT

Experiments in Solomon Islands with live storage of tropical rock lobsters, principally the double spined rock lobster, *Panulirus penicillatus*, have shown that it can be possible and profitable for village fishermen to store their catch for up to six weeks. Mortality over the six-week period varied from zero to 54.8 per cent and averaged 24.0 per cent. Lobsters which were fed during storage had a higher mortality rate than those which were not fed. Mortality was also related to the stocking density, and to the way the lobsters were handled during capture and before storage. It was significantly lower among rock lobsters which lost only a few limbs during handling than in those which lost many. Weight loss during storage, determined by wet weight measurements, was 3.3 per cent and 3.7 per cent for fed and non-fed lobsters respectively. However, when dry weights were considered, the weight loss of fed lobsters was significantly less than that of non-fed lobsters.

Live transport of rock lobsters for periods up to 12 hours was also shown to be feasible using simple methods and readily available materials such as wet sacks or sawdust. For longer transport it was necessary to reduce the carrying temperature with ice.

A set of advisory notes on capture, storage and transport practices is given.

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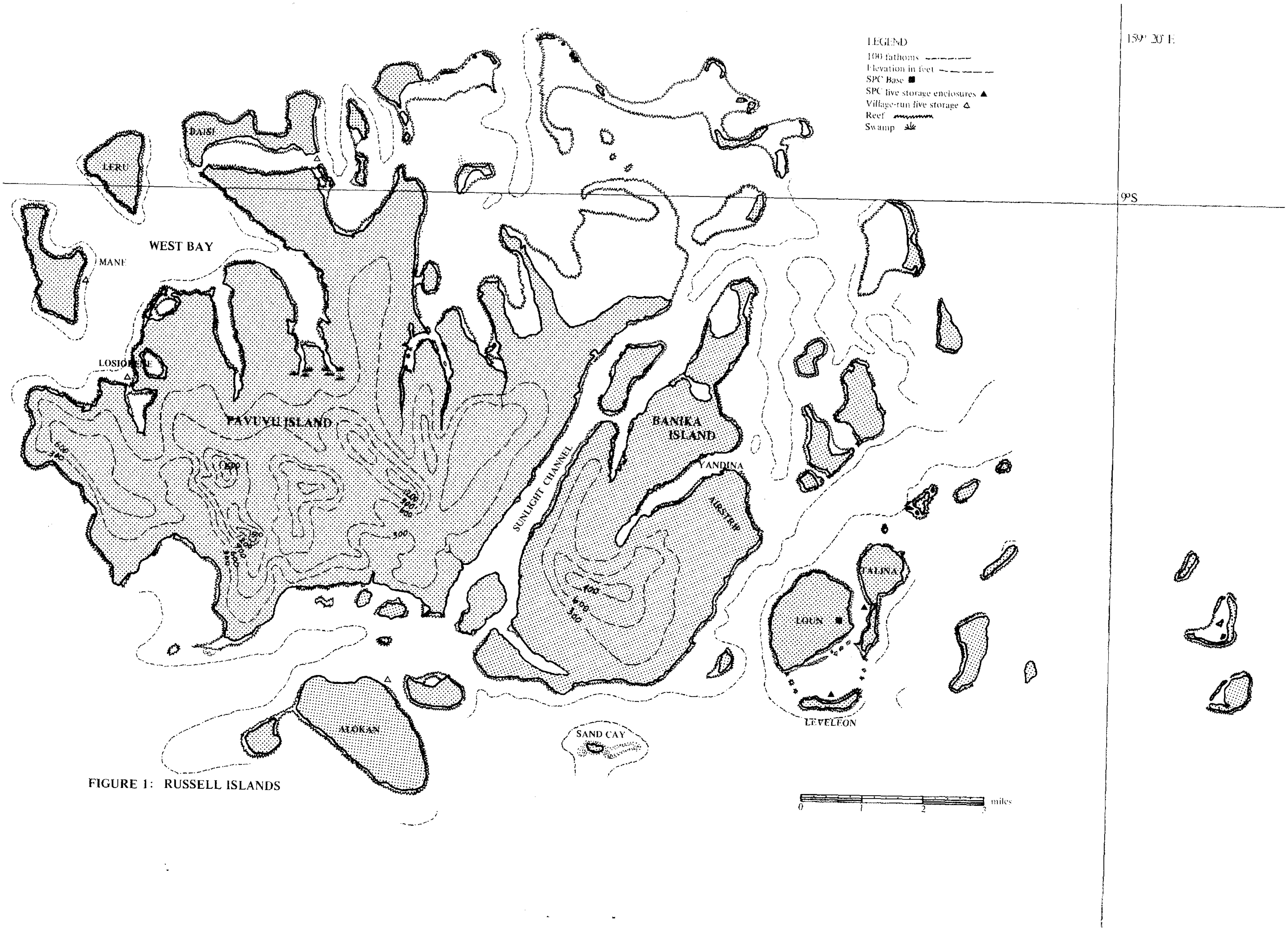

FIGURE 1: RUSSELL ISLANDS

INTRODUCTION

The double-spined rock lobster, Panulirus penicillatus, is found in several extensive areas of Solomon Islands, notably the weather coasts of San Cristobal, Guadalcanal and the Western Province. I would agree with the view of George (1972)[1] that this species offers the greatest potential for exploitation in most parts of the tropical Pacific.

In Solomon Islands the areas where double-spined rock lobsters are found are usually the least developed. Although there are plans to install ice-making and freezing facilities in some of these areas in the future, facilities for processing and freezing rock lobsters are non-existent at the present time. To develop a lobster fishery, the village fisherman therefore needs a method of live storage and transport.

The project described in this report was a continuation of the work started by the South Pacific Commission at Munda, Western Solomon Islands in 1974[2]. The aims were to research and demonstrate the best methods of live storage and live transport of rock lobsters in village situations, and to investigate the economic feasibility of such a fishery. A viable fishery could only be based on a resource with a high enough sustainable yield. The most important economic factor was the fisherman's need for an enclosure in which to store his catch. The materials for this had to be locally available, of reasonable cost, and easily assembled with a minimum of tools and skill, if possible with "bush" materials and traditional skills. The mortality rate and weight loss were also important economic factors. The success of live transport was related to the distance transported, and the means of transport available to the fisherman, i.e. wooden canoe and paddles, outboard motor, government or private shipping, etc. Profitability was related not only to the market value of the rock lobsters, but also to the per capita income of each specific area.

In order to base the project in the best location, diving surveys were made of the Nggela Islands, the weather coast of Guadalcanal (Wanderer Bay area), the weather coast of San Cristobal (Star Harbour District), Santa Ana Island and the Russell Islands. The latter area (Fig.1) was chosen because sufficient lobsters were found during the diving surveys and support facilities and communications were much better there. The project was sited on Loun Island. Local fishermen, mostly from Loun, supplied the lobsters needed for the experiments. Prior to the arrival of this project a few of the local fishermen had traditionally caught rock lobsters by hand while walking on the reefs at night with a torch. They usually marketed their lobsters locally, but some were cooked, frozen in a borrowed freezer and flown to Honiara.

The live storage experiments described here were begun in September 1975 and carried on until March 1977.

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1. George, R.W. 1972: South Pacific Islands - rock lobster resources. A Report prepared for the South Pacific Islands Fisheries Development Agency. FAO, Rome, 42 pp.

2. Bewg, S. 1975: SPC spiny lobster live storage project. Internal report. SPC, Noumea, 26 pp.

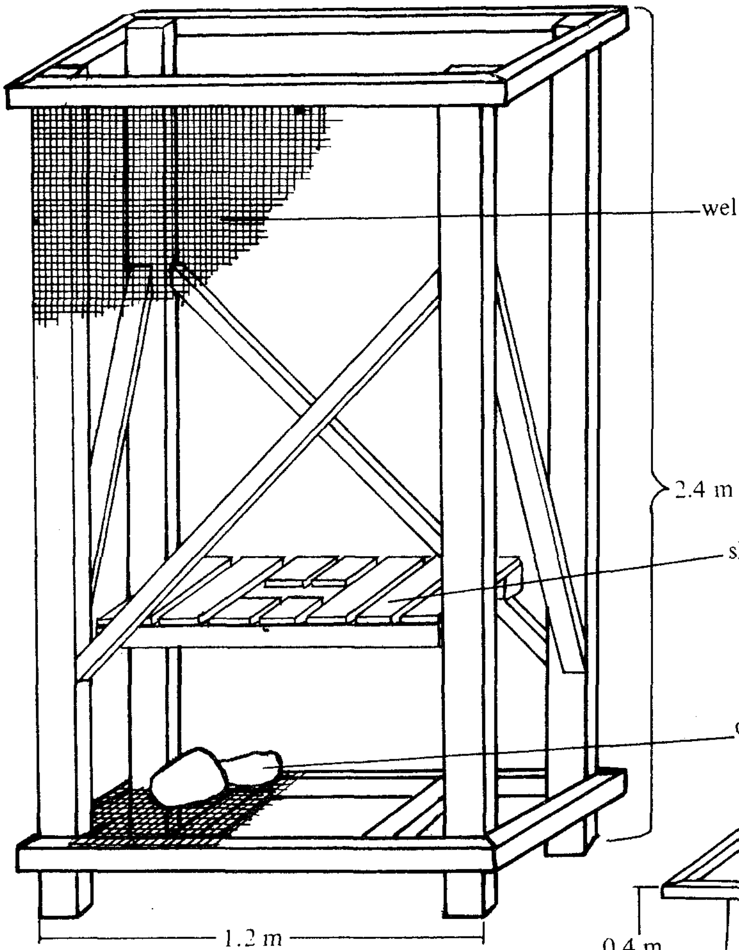

Figure 2 - Live storage pen

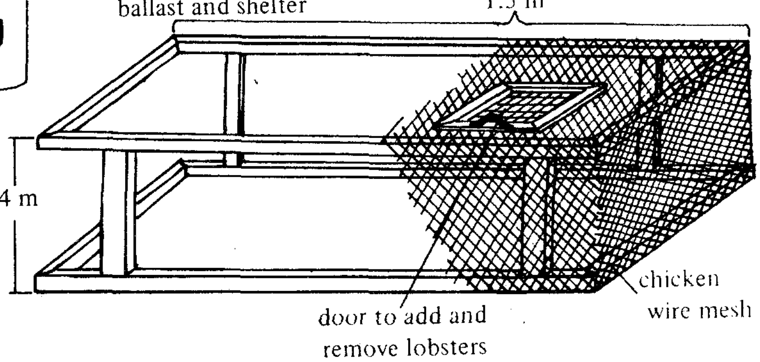

Figure 3 - Live storage cage

LIVE STORAGE

MATERIALS AND METHODS

Two types of enclosures were used for holding the lobsters during this study. The enclosures were called "pens" and "cages" by Bewg during his work in Solomon Islands in 1974. The same names have been retained in this study. The enclosures used in this study were similar to those used by Bewg; however they differed in dimensions and, in the case of the pens, in construction. The dimension and construction plans of the pens and cages are shown in Figs. 2 and 3. Three types of galvanized wire netting and a rigid nylon netting were used to cover both the cages and the pens (Table 1).

Table 1. Netting specifications for lobster pens and cages (★ = brand name)

Name	Material	Diameter mm	Mesh size mm
Chicken wire	galvanized wire	0.75	1.5
Chicken wire	"	1.25	4.0
Weldmesh★	"	1.75	1.5
Netlon★	rigid nylon	3.0	2.5

Mangrove poles, both green and seasoned, and vasa, Vitex cofassus, were used for pen construction. Only vasa was used in cage construction.

All enclosures were sited in areas with good sea water circulation which maintained normal sea water surface temperatures (29.5-30.0°C). Salinity, dissolved oxygen and other water quality criteria were not monitored.

The pens were put into water approximately 1.5-2m deep, depending on the tide. The top of the pen was always exposed for easy loading and unloading. The pens were ballasted with large pieces of dead coral weighing approximately 200 kg. This kept the pens upright in all but one instance, when large waves swept over the low island which normally protected the area. The dead coral provided some shelter for the lobsters. Further shade was provided by a slat floor.

Cages were used in one of two ways. They were either placed on a coral rubble and sand bottom at 10 m or were suspended from a simple bamboo raft with 6 mm nylon rope. The tops of the cages placed on the sea bottom were covered with opaque plastic to provide shade for the lobsters. Cages suspended from the bamboo raft were shaded with coconut leaves, renewed at monthly intervals. The tops of the suspended cages were normally at a depth of 0.5 m, but the cages were occasionally lowered during periods of intense rain which accompanied tropical depressions. This protected the lobsters from the lower salinity surface water.

Most of the lobster fishing for the project was done from four days before the last quarter of the moon until two days after the new moon, between 2000 and 2400 hours. Divers equipped with simple waterproof electric torches, goggles and gloves, dived along the sub-littoral zone[1] of weather coast reefs. They caught the lobsters by hand, usually by grasping the carapace, and then put them into a canoe. The canoe was kept bailed to prevent the lobsters from sitting in water which would become deoxygenated. Other fishermen, equipped only with torches, walked along the sub-littoral fringe[2] and eulittoral zone[3] of weather coast reefs. Their usual method of capture was to step on the lobster's carapace to immobilize it, and then put it into a sack.

When a reef had been covered by the fishermen, which usually took from one and a half to two hours, the lobsters were brought back to base. The catch consisted of lobsters which could be caught by hand, both male and female, including berried females. Each lobster was given an identifying mark by clipping a specific pleopod or combination of pleopods. No more than four pleopods were clipped per individual. Most of the rock lobsters were only out of the sea for 2-3 hours before being put into the enclosures. The following data were kept for each lobster (see Figs. 4, 5 and 6):

Species
Sex and sexual state (i.e. the presence of a spermatophore[4], newly-deposited or late-stage eggs)
Carapace length and total length
Weight
Limbs lost.

Additional data kept for each night of fishing were:

Time and area of fishing
Man-hours fishing effort
Lunar period
Tide
Atmospheric and sea conditions.

Each enclosure was observed from the outside (so as to disturb the lobsters as little as possible) as often as was practicable, usually once a day. Dead or moulted lobsters were noted and dead ones were removed before they became badly decomposed. Some dead lobsters occasionally went unobserved, particularly at higher densities.

The live storage experiments were done as two series. The first series was begun in September 1975. There was no feeding during this series which was planned to show whether mortality was related to the stocking density or the types of enclosure. Either pens or raft-suspended and bottom cages were used to hold all the lobsters caught during one catching period. This meant that one type of enclosure was empty and ready to be used for the next month's catch, and allowed for repairs or replacements, which were often required.

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[1] sub-littoral zone - only briefly exposed at suck-back of waves.

[2] sub-littoral fringe - emersed only briefly at lower than normal tides.

[3] eulittoral zone - fully immersed and emersed at each tide.

[4] spermatophore - contains the spermatozoa in a protective matrix. It is deposited by the male during copulation and appears as a tar spot on the sternum of the female.

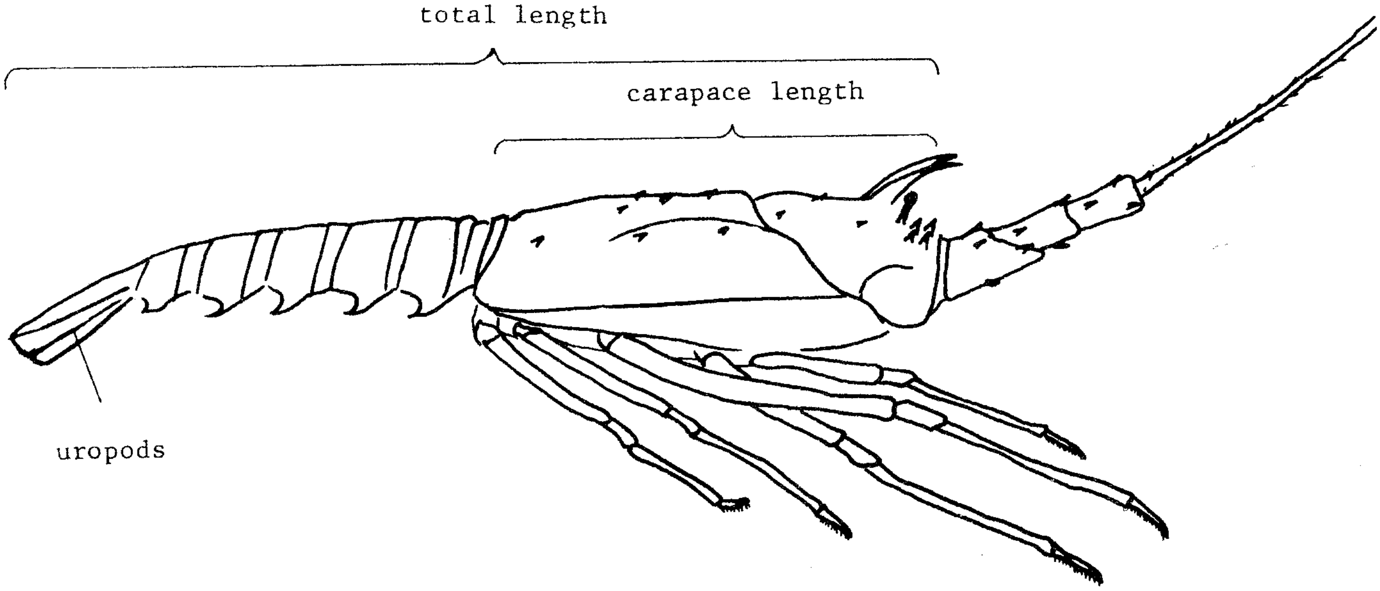

Figure 4 - Schematic drawing of Panulirus penicillatus

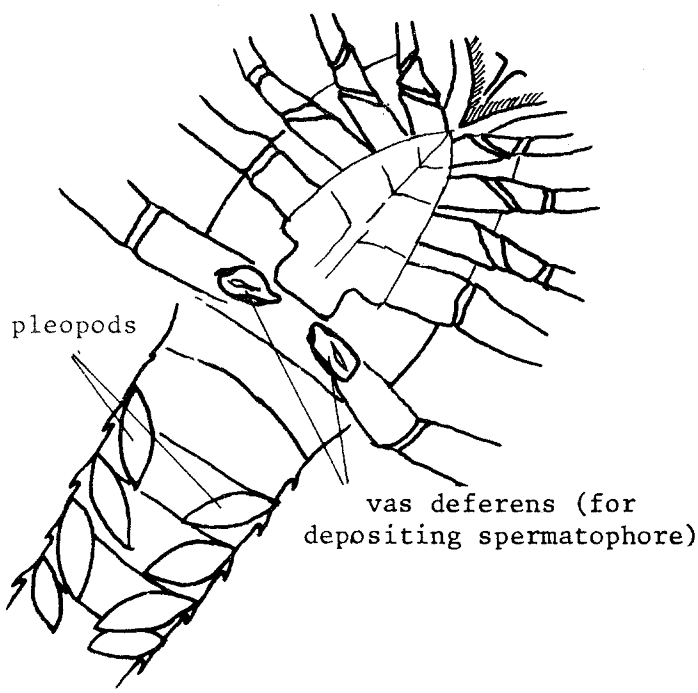

Figure 5 - Ventral view, male lobster

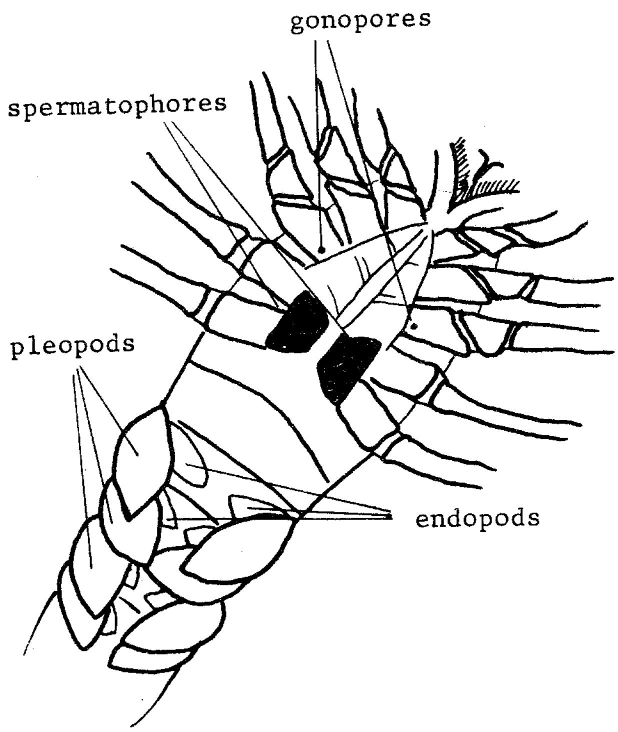

Figure 6 - Ventral view, female lobster

Densities were initially low in the first series and were gradually increased. Attempts were made to have equal densities in each type of enclosure, but in practice this was not always possible. Poor weather and lack of co-operation by the local fishermen often resulted in too few lobsters being caught to fill each enclosure in the desired density. Sex ratio and size frequency of the lobsters used in the experiments were largely determined by the catch that month.

The second series, consisting of experiments with feeding, began in May 1976. The initial densities used in this series were higher than those of the first series. The use of sea bottom cages was discontinued because of the difficulty in handling them. During these experiments the lobsters were fed an excess of food once a day, usually in the evenings, except when food was unavailable or rough seas isolated the enclosures from the project's base. Uneaten food was removed the next day. The principal food was shark flesh which was cut into cubes of about 2.5 cm. Alternatively, teleost flesh or whole chitons were used.

Each live storage experiment was run for about six weeks; lobsters were then removed from their enclosure and brought to the project base. Each lobster was identified by the clipped pleopods, and the following data were recorded:

Sexual state
Carapace length (if the lobster had moulted during storage)
Weight.

To evaluate weight loss, which was not possible by wet weight measurements, dry weight analysis was done for 28 lobsters. Of these 28 lobsters, 13 had not been fed for six weeks, 11 had been fed daily for six weeks and four had only been stored for 12-18 hours. Lobsters selected for this experiment were in good condition (i.e. active, had lost few or no limbs). The females were without eggs. All lobsters had hard exoskeletons but were not at a stage just prior to moulting. This latter aspect was extremely important as the amount of water in the tissues is much higher immediately before moulting, during moulting, and for the period of time after moulting until the exoskeleton has hardened.

Lobsters of near-equal size were dried in pairs, usually one each in various combinations of the fed, non-fed, or newly-caught batches. To facilitate handling during the following steps and to prevent the shedding of any limbs, the lobsters were immersed in a small amount of sea water and allowed to suffocate. After this the lobsters were removed, dropped in a dry towel and swung at arm's length 20 times (10 times in one direction and 10 times in the opposite) to remove free water. They were then weighed to the nearest gram on a Mettler P2010 balance and put quickly into an electric oven, preheated to approximately 110°C. They were placed side by side, ventral side down and dried for 0.07 hours per gram of body weight. They were turned over approximately half-way through the drying process.

After drying lobsters were weighed immediately (to the nearest 0.1 g). Immediate weighing was necessary for accuracy because the dried lobster absorbed water vapour from the air very rapidly. Each lobster was then broken open and examined for complete drying.

DISCUSSION AND RESULTS

MORTALITY

Mortality during the different experiments varied between zero and 54.8 per cent. No significant difference at the 0.05 level by sex or size group was found. Table 2 gives the results for all experiments except those where lobsters escaped from the enclosure, and one where the lobsters were immersed in rain water in the canoe and 40 per cent died within 12 hours. Also included are the results of two control groups from tag mortality experiments.[1] These data are for an initial six-week period, for which conditions were essentially identical to other experiments with feeding.

Table 2. The type of enclosure, the initial number of lobsters in an enclosure (N_o), the stocking density in kg/m^2 and number/m^2, the number of deaths after six weeks (N_d), the percentage mortality (M) and mean mortality ($\overline{M}$).

Enclosure	NON-FED					FED				
	N_o	Density kg/m^2	Density nos/m^2	N_o	M	N_o	Density kg/m^2	Density nos/m^2	N_d	M
Pens	19	1.1	1.7	0	0					
	26	1.7	2.4	1	3.8					
	19	1.9	1.7	0	0	22	1.7	2.0	6	27.3
	40	3.1	3.6	6	15.0	47	3.0	4.3	7	14.9
	81	5.2	7.4	21	25.9	84	5.8	7.6	46	54.8
	95	7.1	8.6	16	16.8	105	6.9	9.5	42	40.0
	Σ = 280			Σ = 44	$\overline{M}$ = 15.7	Σ=258			Σ = 101	$\overline{M}$ = 39.1
Raft suspended cages	8	1.1	1.6	1	12.5					
	9	1.4	1.8	0	0					
	9	2.0	1.8	1	11.1					
	11	1.6	2.2	3	27.3					
	11	1.9	2.2	1	9.1					
	17	2.3	3.4	5	29.4					
	17	2.5	3.4	0	0					
	21	3.0	4.2	5	23.8					
	25	3.6	5.0	7	28.0	25	3.4	5.0	2	8.0
	25	4.0	5.0	0	0	26	4.5	5.2	5	19.2
	36	5.2	7.2	7	19.4	31	4.0	6.2	1	3.2
	43	6.1	8.6	14	32.6	52	6.8	10.8	13	25.0
	61	8.1	12.2	10	16.4	75	9.7	15.0	32	42.7
	Σ = 293			Σ = 54	$\overline{M}$ = 18.4	Σ=209			Σ = 52	$\overline{M}$ = 25.4
Cages	9	1.0	1.8	0	0					
	10	1.3	2.0	3	30.0					
	13	1.7	2.6	1	7.7					
	15	2.1	3.0	1	6.7					
	14	2.3	2.8	2	14.3					
	15	3.6	3.0	4	26.7					
	39	4.5	7.8	14	35.9					
	38	6.3	7.6	10	26.3					
	Σ = 153			Σ = 35	$\overline{M}$ = 22.9					

[1] Tagging experiments were also carried out during this study but are not included in this report.

Effect of capture condition on mortality

In the majority of the experiments most mortality occurred during the first few days of storage. This was presumably due to injuries received during capture. The local fishermen who supplied the lobsters for nearly all the experiments were not always overly concerned with the way they were handled. They were paid A$1.54 per kg for any lobster which appeared healthy, irrespective of whether the lobster died during storage. If the lobsters had been handled more carefully, mortality might have been lower, as might be the case in a village where each fisherman or co-operative is paid only for the lobsters that reach a market. Lobsters which died after the first few days were in many cases those which moulted and were cannibalized while their exo-skeleton was soft.

Mortality was found to be related to the number of limbs lost during capture (Table 3). When these data were tested using the chi-square test a significant difference ($p<0.02$) was found. Unfortunately, no other objective means was found for determining a lobster's initial condition.

Table 3. Effects of limb loss on mortality

Limbs lost	No. of lobsters	No. of dead lobsters	% mortality
$\leqslant 4$	1080	257	23.8
>4	71	26	36.6

It was also found that lobsters which had just moulted and had a soft exoskeleton, or those which would moult within a few days, invariably died if put into an enclosure. Animals in these moult stages were easily detected and were not used in the experiments.

Many lobsters developed small necroses on the soft parts of the body during storage. There were also many lobsters on which the uropods became eroded and blackened. Most of the necroses were probably due to small injuries during handling when the lobsters clung to each other. Although these necroses were unsightly, they probably caused the lobsters little harm, and did not seem to affect their marketability in Honiara. However, they could cause some trouble if the lobsters were exported.

Effect of stocking density on mortality

Mortality was variable at many of the stocking densities, and was most noticeable in raft-suspended and sea bottom cages used in experiments without feeding. A positive relationship between stocking density and mortality was found, however. The Olmstead-Tukey test was applied to the following data sets: (a) raft-suspended and sea bottom cages without feeding (test statistic 12.5, probability 0.02); (b) pens without feeding (10, 0.1); (c) raft-suspended cages with feeding (10, 0.1).

Data from the pens, with and without feeding, and from the raft-suspended cages with feeding were used to calculate linear regressions (Fig.7). In each case the regression equation appeared to describe adequately the relation of mortality to the stocking density. There was no apparent relationship for raft-suspended and sea bottom cages.

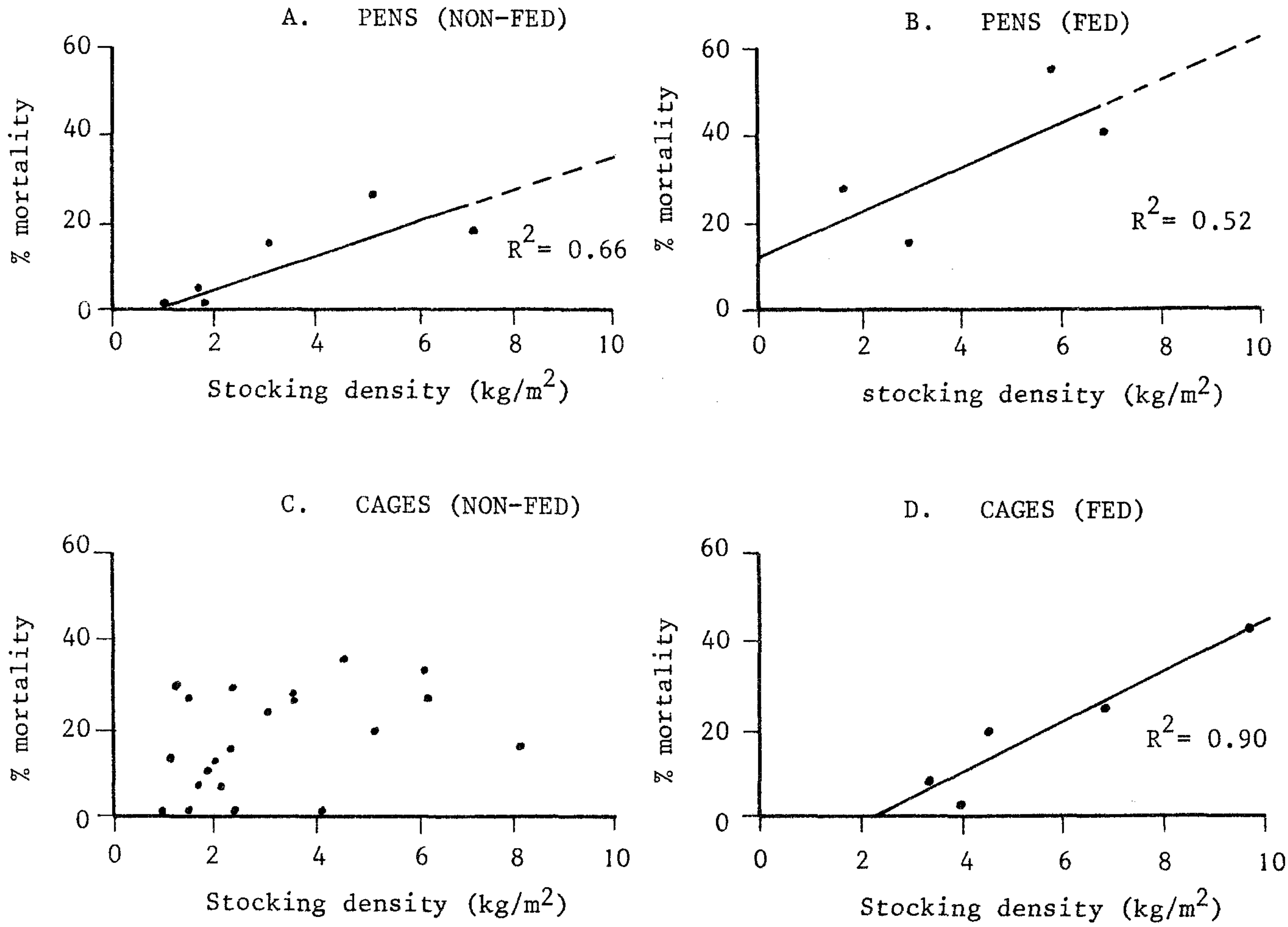

Figure 7 - The effect of stocking density on mortality. Regression equations for A, B and D are: $y = 3.68\ x - 2.1$, $y = 5.1\ x + 12.1$, $y = 5.7\ x - 12.85$.

Data from experiments in the pens were not analysed with those from the cages because of the different way in which surface area of the pens and cages was used by the lobsters. Lobsters in the pens tended to crowd into a comparatively small area making the effective density higher in these enclosures. Surface area available to the lobsters also changed with the tides.

The general behaviour of the lobsters during live storage was a tendency to aggregate during daylight, and disperse and become active at night. The fact that the lobsters formed large aggregations possibly increased the mortality, particularly at higher stocking densities. Lobsters at the bottom of an aggregation were effectively trapped there and could have suffered as a result. It was not uncommon to see lobsters shed limbs as an aggregation dispersed rapidly when disturbed.

Effect of feeding on mortality

Feeding was shown to be unnecessary for up to six weeks. In fact, feeding was undesirable because mortality was higher in the fed experiments than the non-fed. In the experiments in pens the mortality of fed lobsters was more than double (39.1%) that of non-fed lobsters (15.7%). The range of densities was similar for these experiments (see Table 2). In the experiments in raft-suspended cages the average density in the fed experiments was higher than in the non-fed experiments. However, a comparison of the mortalities of the five highest densities of each, which are similar, showed that mortality in the fed experiments was 25.4 per cent compared to 20 per cent in the non-fed.

Reasons for the higher mortality in the fed experiments could be competition for food, resulting in injury, or uneaten food decomposing in the enclosure.

Effect of type of enclosure on mortality

No firm conclusions can be drawn about the merits of different enclosure types. In the non-fed experiments mortality was lowest in the pens and highest in the cages, but these differences were not significant. In the fed experiments the only two enclosure types used were pens and raft-suspended cages (Table 2). Mortality was significantly higher ($p<0.01$) in the pens. However, since this reversed the trend in the non-fed experiments, it was probably the result of some other factor than enclosure type.

To avoid aggregations of lobsters in the enclosures, a means of subdividing the interior would be advantageous. This would prevent lobsters being trapped for long periods, and give them more surface area to cling to. It should be kept in mind, however, that it is important to be able to reach all parts of the enclosure so that dead lobsters can be removed.

Effect of environmental conditions on mortality

Apart from the factors discussed above it was sometimes impossible to explain occasional high mortality. During all experiments where high mortality occurred, environmental conditions appeared normal. Certainly much wider fluctuations in sea water temperature and salinities occurred during tropical depressions, but there were no unusually high mortality rates associated with these. The most unusual situation took place during an experiment where lobsters were kept in two pens only 1 m apart; in one pen there was suddenly very high mortality on one day, but in the other pen only one death. Village fishermen may have to expect occasional high mortality and depend on a low average mortality for a successful operation.

WEIGHT LOSS

Wet weight

During all storage experiments the lobsters lost body weight whether they had been fed or not. The average weight loss from a sample of 577 unfed lobsters was 3.7 per cent and the average weight loss from a sample of 277 fed lobsters was 3.3 per cent. Most of this was the result of eggs being shed during storage, and some due to loss of limbs during storage.

Dry weight

The weight before drying (initial weight), the dry weight, and the percentage weight loss for batches of non-fed, fed and newly caught lobsters are set out in Table 4. The mean weight loss of the fed lobsters (66.8%) was significantly less ($p < 0.05$, t test) than both the non-fed (73.2%) and the newly caught (71.2%); the latter two were not significantly different from each other.

Table 4. Dry weight analysis of fed, non-fed and newly-caught *Panulirus penicillatus*.

NON-FED				FED				NEWLY CAUGHT		
Sex	Initial wt. (g)	Dry wt. (g)	% wt. loss	Sex	Initial wt. (g)	Dry wt. (g)	% wt. loss	Initial wt. (g)	Dry wt. (g)	% wt. loss
M	686	209.7	69.4	F	612	201.7	67.1	962	310.3	67.8
M	429.6	114.0	73.5	F	787	252.3	68.0	885	222.6	74.9
M	649	162.7	74.9	F	728	243.0	66.6	619	169.2	72.7
M	675	189.9	71.9	F	731	243.6	66.7	533	168.5	69.4
M	771	194.2	74.8	F	832	280.0	66.4			
M	546	142.9	73.8	F	614	185.1	69.9			
M	520	135.3	74.0	M	696	241.0	65.4			
F	421	108.6	74.2	F	463	166.5	64.0			
M	770	200.5	74.0	M	1260	455.1	63.9			
F	800	213.0	73.4	M	679	194.0	71.4			
F	610	156.2	74.4	M	804	273.4	66.0			
F	560	174.1	68.8							
F	674	169.2	74.9							
		Average	73.2			Average	66.8		Average	71.2

Because the mean weight loss of non-fed lobsters was only 0.4 per cent more than that of the fed lobsters when measured by wet weights, but was 6.4 per cent more by dry weight, it is suspected that the non-fed lobsters were replacing their metabolised tissues with water. The higher amount of water in the tissues of the non-fed lobsters did not appear to affect the quality of the meat.

To investigate the effects of storage on lobster quality two batches of lobsters which had been live-stored for eight weeks, one fed and one not, and one batch caught a few days before were marked and cooked together. The meat was removed from the lobster tails of each batch, and cut into cubes which were then served on separate, numbered dishes to a panel of 13 people. The meat from each batch was sampled by each person two or more times. The results of the test are shown in Table 5.

Table 5. Results of the lobster taste test.

	Fed for 8 weeks	Non-fed for 8 weeks	Newly-caught	No difference
1st choice	7	4	1	1

The whole panel agreed that the meat from all three batches was of good quality.

ENCLOSURE TYPE AND MATERIALS

The local hardwood, vasa, was found to be much more suitable than mangrove for enclosure construction. Vasa remained resistant to marine borers for a long period of time. For example, one pen made of 10 cm x 10 cm and 5 cm x 5 cm timber was still structurally sound after continual submersion for 25 months. Mangrove timber had a life of approximately six months. As some of the materials used to cover the frame of an enclosure were expensive, it was important to have the frame last a long time. Table 6 summarises the costs and merits of the various types of netting used to cover the enclosures. The approximate cost for cages is based on a frame of 5 cm x 2.5 cm vasa timber which cost A$3.70; for pens a 5 cm x 5 cm vasa timber frame cost A$15.40[1].

Table 6. Cost and suitability of materials for construction of pens and cages; figures in brackets indicate netting costs only.

Material	Cost A$	Approximate work life (months)	Suitability	Construction cost	
				Pen	Cage
Chicken wire (.75 mm dia.)	.50/m^2	< 6	Unsuitable for any application. Easily broken through by lobsters.	(7.20) 22.60	(2.50) 6.20
Chicken wire (1.25 mm dia.)	.50/m^2	9 - 12	Suitable for raft-suspended cages only.	(7.20) 22.60	(2.50) 6.20
Weldmesh (1.75 mm dia.)	2.00/m = lowest retail pr.	6 - 9	Probably suitable for any application.	(28.80) 44.20	(10.00) 13.66
Netlon[2] (3.0 mm dia.)	2.00/m^2	36	Probably suitable for any application.	Similar to weld-mesh.	

[1] Price of timber based on A$0.57 per super foot (1977).

[2] Not currently available in retail outlets in Solomon Islands.

A strong wire netting was necessary to keep the lobsters from breaking through and escaping, and to keep large predators out. Lobsters were easily capable of chewing through the light gauge chicken wire (Fig.8). Chicken wire of 1.25 mm diameter was not broken through when used in raft-suspended cages, but was often broken through in pens and sea bottom cages. Weldmesh which was in good condition was never damaged by lobsters or predators. Netlon was entirely satisfactory when it covered cages which had additional slats at 7.5 cm centres. It has also been used successfully in another Fisheries Division project in the Solomons (Braley, personal communication). This material, unlike chicken wire netting, is very rigid, and providing it is stretched very tightly over the enclosure frame, it is doubtful that the lobsters could get it into their mandibles to chew.

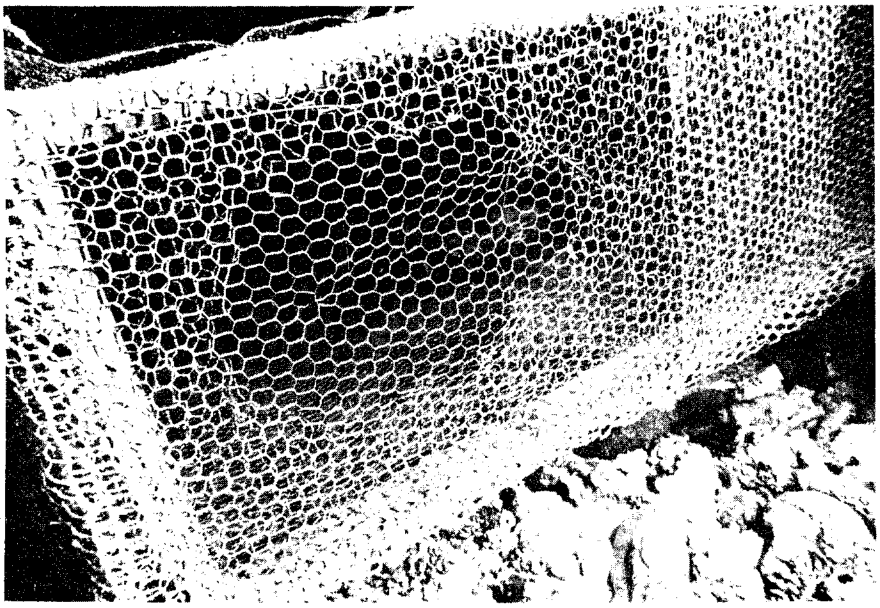

Figure 8 - Sea bottom cage covered with two layers of chicken wire (0.75 mm diameter, 1.5 cm mesh) showing the inner layer chewed away. The outer layer is also starting to be broken.

The selection of the type of enclosure for a particular situation should be determined by the local conditions. For example, if there are areas of calm water, pens or raft-suspended cages may be most suitable. If there are no areas of calm water, bottom cages may be best. Cages were by far the least expensive way to store lobsters. However, if there are large numbers of lobsters, a pen could be worth the added expense as it is the most convenient enclosure.

It is important to make the frame of timber with a similar working life to the netting used for covering it. Vasa was of variable quality, so there was considerable difference in the length of time it remained usable. Vasa which is very dense and contains a lot of sap is best. Other very good hardwoods are known by the local people and could be used if vasa is unavailable.

LIVE TRANSPORT

MATERIALS AND METHODS

A total of 457 P. penicillatus were transported by the following methods:

1. Packed between wet jute sacking in canoes and on board local inter-island ships.
2. Packed in layers in wet or dry sawdust on board local inter-island ships.
3. Packed in layers between dry jute sacks at temperatures ranging from 12-22° C in a refrigerator body. Ice was used as a coolant.
4. Packed as (3) above but with wood shavings substituted for dry sacks.

Lobsters for each experiment were picked at random from batches which had been stored for varying lengths of time, with and without feeding. For each transport experiment the following data were kept:

1. Live storage period prior to transport.
2. Fed or non-fed.
3. Initial number of lobsters.
4. Time at which the lobsters were examined during transport, and the number dead at that time.

Air temperatures inside the refrigerator body were recorded for those experiments; ambient air temperatures and beneath-wet-sack temperatures were recorded for some other experiments.

In every experiment lobsters were packed together as tightly as possible to limit their movements. The sacks were the type used for holding copra. They were washed in sea water before use, and soaked periodically during transport. The sawdust came from mixed local hardwoods except vasa which was not used because it had strong staining properties. Sea water was used to wet the sawdust. Lobsters transported in the refrigerator body were kept dry from the melted ice. The door on the refrigerator body was opened at approximately 6-hour intervals to allow fresh air to enter and to check for dead lobsters. Figures 9 and 10 show how the lobsters were packed in the project's fibreglass canoe and refrigerator body.

RESULTS AND DISCUSSION

Wet sacking

Wet sacking was an effective means of reducing the temperature by 2-3°C during transport in shaded conditions. The temperatures during one transport experiment on the government vessel Waitaro are shown in Table 7.

Table 7. Ambient and beneath-wet-sack temperatures (°C) recorded during one live transport experiment.

Time	1000	1100	1200	1300	1400	1500
Ambient air temperature	30.0	30.0	29.5	30.5	30.0	30.0
Beneath-sack temperature	26.8	27.5	27.5	27.5	28.0	27.0

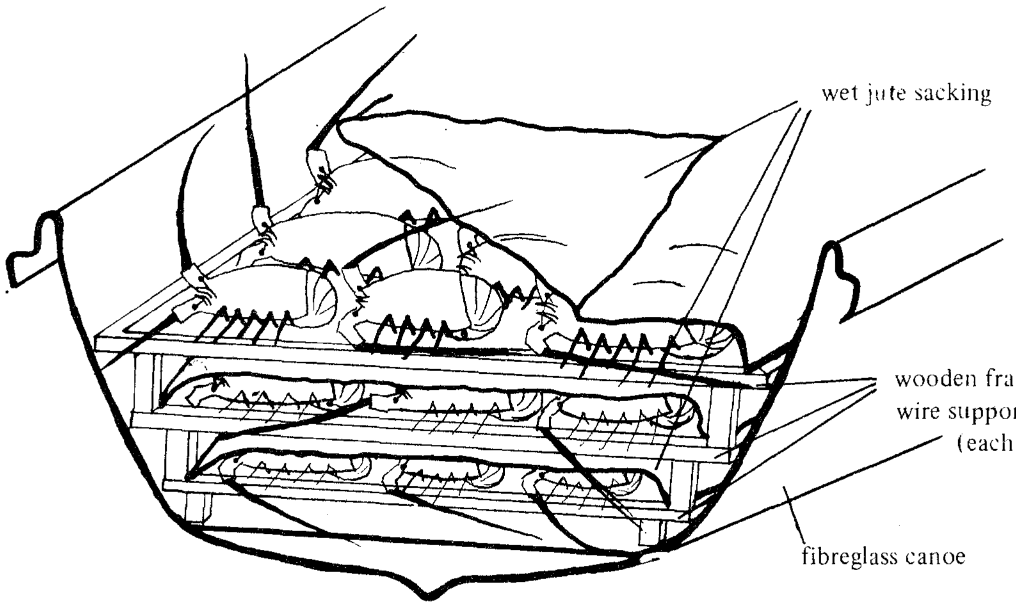

Figure 9 - Cross-section of canoe showing the packing method for live transport

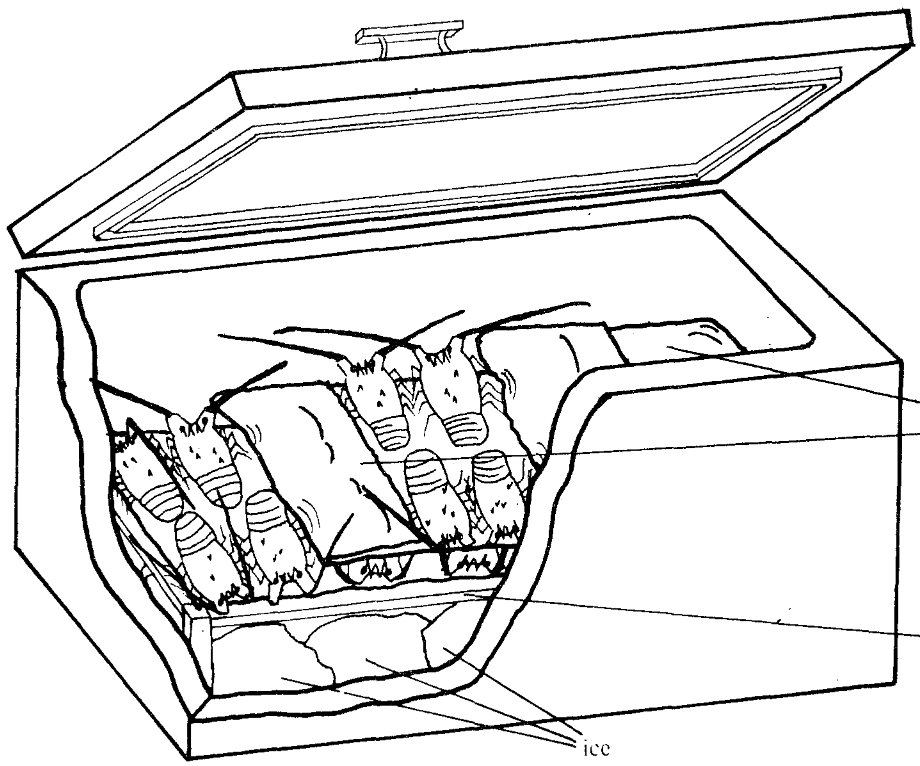

Figure 10- Cut away of refrigerator body to show packing method for live transport.

Although the wet sacks were unshaded during canoe transport, the temperatures were reduced because of rapid evaporation from constant air movement. Mortality increased once the canoe was beached, as temperatures rose quickly, even with regular wetting of the sacks.

The mean mortality for lobsters transported in wet sacking was 10 per cent for periods of transport of 8 hours or less (see Fig.11). There appeared to be a considerable difference between mortality during transport of batches of lobsters stored 7-10 days and of some batches stored for 42 days. The lower mortality for the 7-10 day batches had a strong influence on the mean mortality as there were larger numbers of lobsters in these batches.

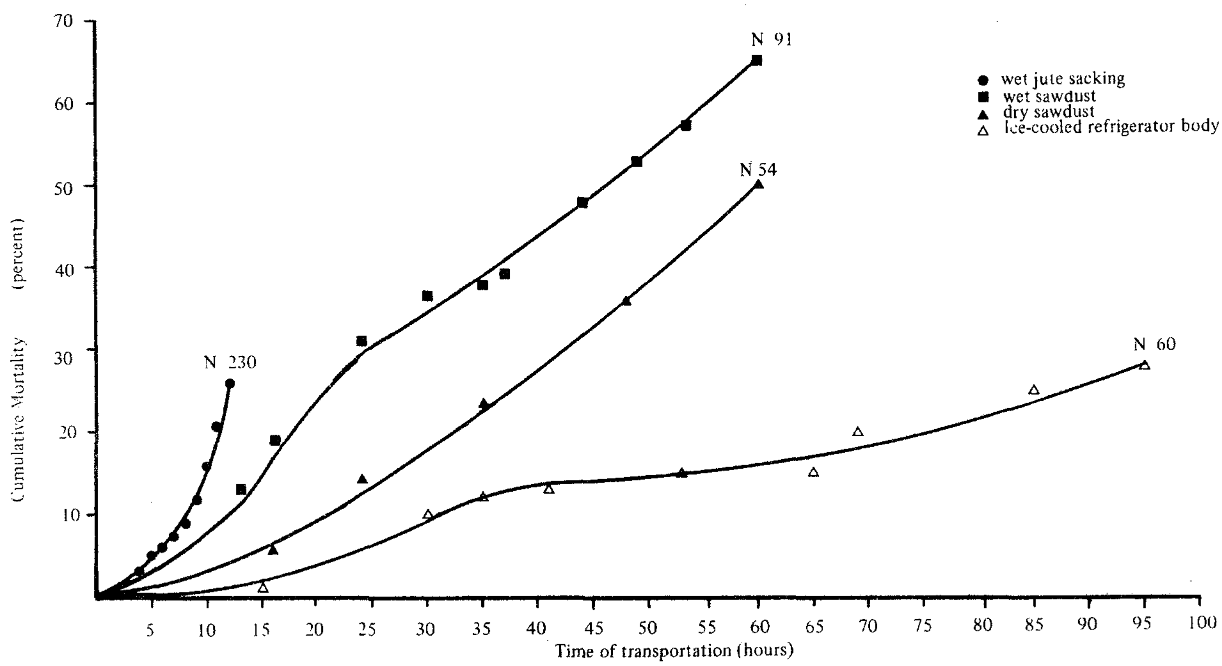

Figure 11 - Cumulative mortality during live transport

Live transport in wet sacks is a method that village fishermen working near a market could use successfully. The temperature was reduced so long as there was shade, or if in a canoe, as long as it was underway. Regular soaking of the sacks could be difficult on large, fast ships while they are underway, and wetting the decks could be a problem in confined spaces if there are many passengers.

Wet and dry sawdust

Both wet and dry sawdust insulated the lobsters against the sun and also prevented rapid drying of the gills from wind. The mean mortality during live transport using dry sawdust was lower than that of wet sawdust (see Fig.11), but this was not always the case for individual experiments. In an early experiment using both wet and dry sawdust, too much wet sawdust was used in each layer and the lobsters on the bottom layer might have suffocated when the wet sawdust became compacted.

Sawdust was readily available in the Russell Islands and many other parts of Solomon Islands where there were small sawmills operating. One drawback of using wet sawdust was that it was very heavy. Dry sawdust could be used many times, as could wet sawdust, providing it was dried between times. In general sawdust was a better packing material than wet sacks. Dry sawdust, because it is light, is very suitable for air freight.

Ice-cooled

Using approximately 20 kg of fresh water ice, the mean temperature was 16.2°C over a 96-hour period during one experiment (Fig.12), and a similar temperature was maintained in other experiments. At this temperature, the lobsters became very inactive and it was often difficult to tell whether they were alive or not. Packing the lobsters between dry sacks and cooling by ice was the most effective method of reducing mortality during transport, particularly for periods of 12 hours or more.

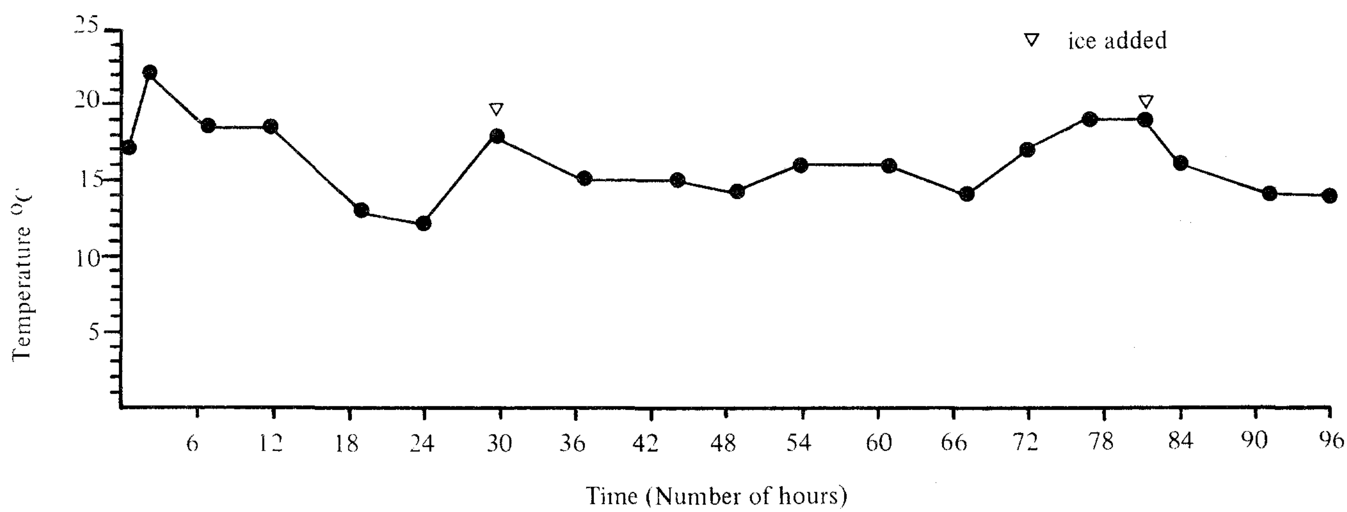

Figure 12 - Air temperature inside refrigerator during transport.

Results were very poor when wood shavings were substituted for dry sacking. After 27 hours (the first check for mortality) 14 out of 21 lobsters (67%) were dead. The remaining seven lobsters were all on top of the shavings, and were still alive 11 hours later. It was possible that the dead lobsters had suffocated. This method was not tried again.

The refrigerator body was not convenient because it was heavy and awkward to get aboard canoes and local ships; also fewer lobsters could be shipped because of its bulk. It was also less practical because a supply of ice was needed.

However, live transport in the ice-cooled refrigerator body showed that mortality could be significantly reduced at lower temperatures. This is particularly important because ice will soon become available in many parts of the Solomons. Large, insulated ice-boxes could be fitted in local vessels for carrying live lobsters at moderate cost.

The way in which lobsters are handled and processed is extremely important in producing a high quality product, particularly in the tropics where spoilage occurs very rapidly. To ensure a high quality product the lobsters should arrive at the market alive.

Two economic studies of lobster fishing were made for the Russell Islands, one based on fishing 120 nights per year, the second on 60 nights per year. The catch rate of 5.5 lobsters per man per night dive used in these studies was the average catch in a random sample of 100 night dives made by local fishermen during the project. The maximum number of nights during the low moon period (four days before the last quarter to two days after the new moon) was estimated to be 120. This estimate was made from records kept on the nights when weather and sea conditions permitted diving. When the study areas were too rough, usually a reef could be found among the islands in the Russells which was protected from the direction of the wind or swell. The 25 per cent mortality rate used in the calculations takes into account a 23 per cent mortality rate during live storage and a 2 per cent mortality rate on the short trip to Honiara. The average weight of the lobsters in the storage experiments was 0.73 kg and this was used to calculate the estimated annual catch. Lobsters normally sold for $1.54/kg and this figure was used to calculate the value of the catch.

Two costings have been made based on (1) two fishermen working together, and (2) three fishermen working together (Table 8). It was found in practice that most of the reefs in the Russels could be most efficiently fished by either two or three fishermen (usually three fishermen worked together).

Table 8. Economics of lobster fishing in Russell Islands using a locally made canoe with 6 HP outboard costing A$500 and depreciated over four years. (Values shown were those current in early 1978).

Earnings/year/man			
120 nights/year, 5.5 lobsters/night, 25% mortality, 493 lobsters/year, 0.73 kg/lobster, 360 kg/year, $1.54/kg			A$555.00
Expenses/year/man			
	2-man operation	3-man operation	
Depreciation of boat	68.75	48.80	
Fuel 8 l/night, 22c/l	105.60	70.40	
Maintenance	25.00	16.70	
Equipment (goggles, torch, gloves)	15.00	15.00	
Batteries	35.00	35.00	
Storage cage	15.00	15.00	
Shipping	22.50	15.00	
Total expenses	A$286.85	A$215.90	
Balance		(2-man operation)	A$268.15
		(3-man operation)	A$339.10

A similar calculation based on 60 nights fishing/year gives a balance of $84.70 for a 2-man operation and $133.15 for a 3-man operation.

The selection of the canoe for the purposes of this study was made on the basis of personal observations of canoe and engine preference by the Russell Islands fishermen. Many such combinations are being operated there at the present time.

The economics of the above studies clearly show that it could be profitable for a group, or groups, of fishermen to catch lobsters in the Russell Islands and market them in Honiara. Based on three hours of work per night (1.5 hours diving per night), each man of a group of three, for example, diving 120 nights per year would make a net profit of $0.95 per hour, and if he dived only 60 nights a year, his net profit would be $0.74 per hour. Both of these rates are far higher than the national average income. The profitability is further increased when it is taken into account that the canoes could also be used for other forms of fishing and carrying market produce, copra and passengers.

Although the profitability of this kind of fishing is probably higher in the Russells than other areas, the conditions are similar to areas such as Marovo Lagoon and West Guadalcanal. It should also be taken into consideration that in areas where profits will be lower because of increased transportation costs and possibly higher mortality during transport, local incomes are also likely to be lower. Nevertheless, much lower profits than shown here could still be an important cash income to the people.

CONCLUSIONS

Live storage is a realistic answer to the problem of developing a village-level lobster fishery. Live storage and live transport techniques are easily learned by village fishermen. Initial investment is small, and can be recovered quickly. The economics of the fishery, based on this study, show it could provide a profitable cash income in many parts of the Solomons.

ADVISORY NOTES ON LOBSTER CATCHING, STORAGE AND TRANSPORT PRACTICES

I. FISHING

1.1. Catch per unit of effort can be maximised in the following ways:

1.1.1. Night diving or torching should be done during the low moon period, when lobsters are most abundant.

1.1.2. The number of divers and fishermen torching on the reef should be limited so that each man can cover his own area of reef and not overlap another.

1.1.3. Fishing should take place when weather and sea conditions are favourable.

1.2. For live storage lobsters must be in good condition. This can be assisted in the following ways:

1.2.1. The lobster should be caught carefully by grasping the carapace. If the legs or antennae are grasped the lobster will shed them, and if it is eventually caught, it is less likely to survive. Grabbing the tail can injure the lobster internally. Lobsters that are in holes and cannot be caught without a struggle should be left for another time.

1.2.2. Fishing should not take place during periods of heavy rain. Rain water will quickly kill the lobsters if they are allowed to sit in it. If it begins to rain after fishing has begun, the lobsters should be covered in some way.

1.2.3. Lobsters should be put quickly into a sack and carried by the fisherman, or into a canoe in which water is not allowed to accumulate. If put in a canoe they should be covered with sacking. A basket in the canoe is the best way for each fisherman to keep his catch covered and separate.

1.2.4. Lobsters should be put into a storage enclosure as soon as possible. Handling at this point is important; if a bucket or sack is used to hold the lobsters, it is best, in the case of pens, to put the whole bucket or sack into the pen where the lobsters can be tipped out gently without individual handling. If cages are being used, individual handling will be necessary. The lobsters should be tipped carefully out in the bottom of the canoe. Usually the lobsters separate from each other and it is unnecessary to pull them apart, which may injure them.

1.2.5. Lobsters which have just moulted and have a soft exoskeleton or are going to moult within a few days[1] should be left on the reef. If caught they should be processed or eaten immediately, as they usually die during storage.

[1] To determine this, firmly grasp and squeeze the carapace; the brittleness of the shell is evident by a slight crackling.

II. STORAGE

2.1. Low mortality during storage can be best assured by attention to the following points:

2.1.1. The lobsters must be in good condition.

2.1.2. The enclosures should be put in an area which is not susceptible to fresh water run-off, such as near river mouths. Less obvious is fresh water seepage. It can be seen where fresh water mixes with the sea water, or felt as it seeps out because it is usually cooler than the sea water.

2.1.3. The enclosures should be in an area where there is good sea water circulation.

2.1.3.1. Sea water circulation should maintain water temperatures no higher than those in the lobsters' natural habitat.

2.1.3.2. A high level of dissolved oxygen should be maintained by good circulation.

2.1.3.3. Circulation should be sufficient to carry away waste products from the enclosures.

2.1.4. Site the enclosure in an area as safe from storm damage as possible.

2.1.5. Direct sunlight is harmful to lobsters. Shade should be provided at all times.

2.1.6. Dead lobsters should be removed before they become badly decomposed.

2.1.7. Do not feed the lobsters.

2.2. Other considerations of live storage:

2.2.1. The best materials locally available should be used for the construction of the enclosure type best suited for local conditions. The cost of materials and the number of lobsters being handled should be kept in mind.

2.2.2. The enclosure should be maintained in good condition and checked as frequently as possible. Frequent checking will minimize the possibility of escape through holes made by the lobsters or predators.

2.2.4. The lobsters should be taken to market or sold as soon as practicable after capture.

III. TRANSPORT

3.1. Whenever possible all handling and transport should be done during the night or early morning to minimize the effect of sunlight.

3.2. Lobsters should be removed carefully from the enclosures and put quickly into the packing material to avoid drying of the gills.

3.3. Lobsters should be packed and transported by the method most practical for a particular situation; dry sawdust is the most generally useful packing material.

3.4. Lobsters should be packed tightly to limit their movements and to make most efficient use of space.

3.5. All packing materials should be clean and free from toxic substances.

3.6. The carrying temperature should not exceed that of the sea water in the lobsters' natural habitat, which is approximately 29-30°C in the central Solomons. In the case of wet sacks or sawdust, ensure continual evaporation and protect the lobsters from direct sunlight. Sacks should be wetted with clean sea water regularly, and no excess should be allowed to accumulate and form pools around the lobsters.

3.7. Lobsters should be checked periodically during transport over extended periods. Dead lobsters should be removed and discarded or, alternatively, if a good quality product can be ensured, cooked and eaten, or frozen immediately.

3.8. To avoid delays, arrangements for selling the lobsters should be made before transport.

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