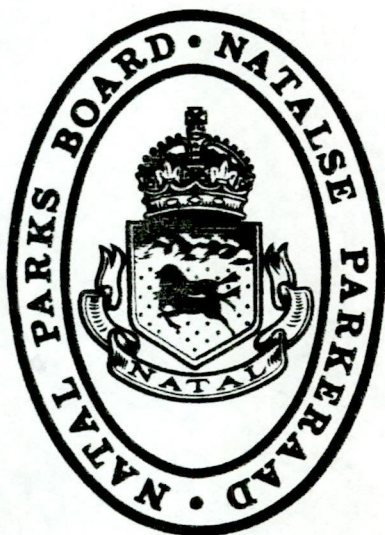


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SUBSTRATUM PARTICLE SIZE : A LIMITING FACTOR IN THE DISTRIBUTION
OF PENAEUS JAPONICUS IN ST LUCIA

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ABSTRACT

Three categories of P. japonicus juveniles; small (carapace length of 3 - 10 mm), medium (carapace length of 11 - 17 mm) and large (carapace length of 18 - 25 mm), were allowed a choice of twelve substrata with particle sizes ranging from less than 63 μm to 4 000 μm . Each category of prawns was tested separately and each experiment was replicated ten times. Results showed that the distribution of the prawns in the various substrata was not random, with P. japonicus juvenile of all three size categories exhibiting a statistically significant preference for substrata with a particle size of 355 - 500 μm . They significantly avoided substrata with particles smaller than 180 μm in diameter. The preponderance of substrata with a mean particle size smaller than 200 μm that was found to exist in the St Lucia system could thus be the factor limiting the abundance of P. japonicus in the system.

INTRODUCTION

Five species of penaeid prawns were recorded in the St Lucia estuary by the University of Cape Town in their survey 1948 - 1965, namely : P. indicus, P. monodon, P. semisulcatus, Metapenaeus monoceros and P. japonicus. Of these, P. japonicus and P. semisulcatus were taken in very low numbers. (Millard & Broekhuysen 1965, Joubert & Davies 1965; Champion 1976). Forbes (1985) noted that despite the much higher recruitment of P. japonicus larvae into the system, the number of juveniles netted was far lower than for the other penaeid prawns of the St Lucia system.

Forbes (1986) has suggested that there may be a relationship between abundance of P. japonicus in the St Lucia system and the ^{availability?} abundance of a suitable substratum in that system. The present study was designed

to investigate any substratum preference that P. japonicus juveniles may show, with a view to assessing the acceptability of the substrata of the St Lucia system to this species.

MATERIALS AND METHODS

Juvenile P. japonicus were caught in Durban bay off the sand bank shown in Fig. 1. The prawns were caught with a seine net on the sand bank on the low outgoing tide at night.

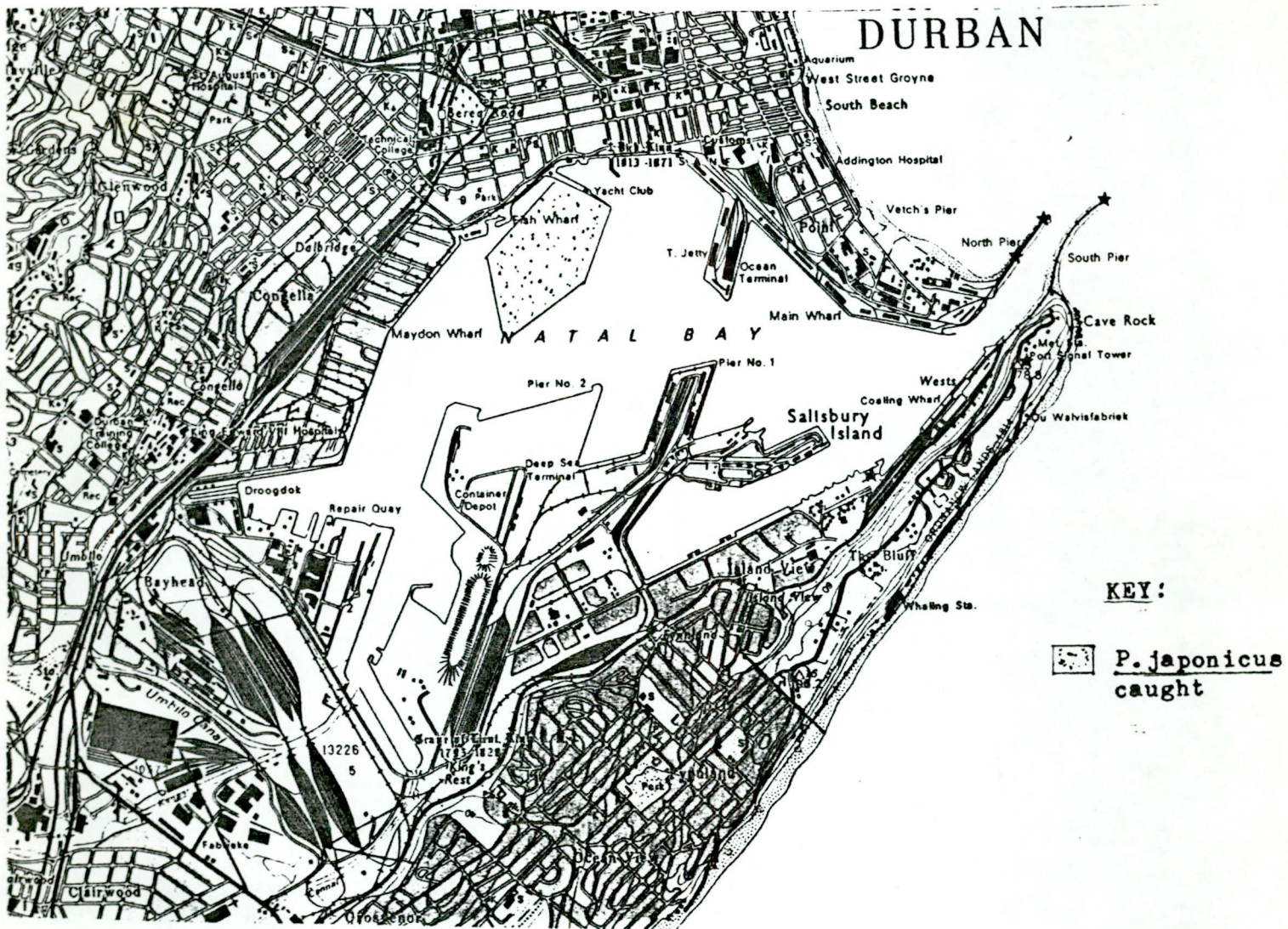


FIG. 1. Durban bay showing the area where the P. japonicus specimens were caught.

The prawns were transported to the laboratory in 25^l aerated containers. The specimens were then divided into three size categories based on carapace length, before being placed in holding tanks. The three prawn size ranges were 3 - 10 mm (small), 11 - 17 mm (medium), and 18 - 25 mm (large). The holding tanks contained standard sub-gravel filters and natural sea water at a salinity of 35 parts per thousand. The temperature was maintained between 19°C and 22°C. Since sufficient natural light entered the laboratory, a natural light/dark cycle was maintained. Feeding took place every third day and consisted of finely chopped squid. This was supplemented with a commercial fish food.

PREPARATION OF SUBSTRATA

Experimental substrata were prepared from natural sediments collected from Durban beach, Umdloti beach and the Beachwood mangrove swamps. These were washed in tap water, oven dried at 150°C and then sieved through a stack of Endecott sieves. A mechanical shaker was used to sieve the substrata for 15 minutes. The very fine fraction (125 µm and less) was prepared by crushing the oven dried mangrove sediment prior to sieving. The twelve fractions that were retained (table 1) formed the test substrata.

TABLE 1. Categories and particle sizes of sediments used in substratum preference tests. Terminology used to describe particle size and grade scales from the Wentworth system.

SUBSTRATUM	PARTICLE SIZE (µm)
1. Silt and clay	< 63
2. Very fine sand	63 - 125
3. Fine sand	125 - 180
4. Fine sand	180 - 250
5. Medium sand	250 - 355
6. Medium sand	355 - 500
7. Coarse sand	500 - 1000
8. Very coarse sand	1000 - 1400
9. Very coarse sand	1400 - 2000
10. Granules	2000 - 2800
11. Granules	2800 - 4000
12. Granules	4000 - 6000

EXPERIMENT 1 - SUBSTRATUM PREFERENCE TEST

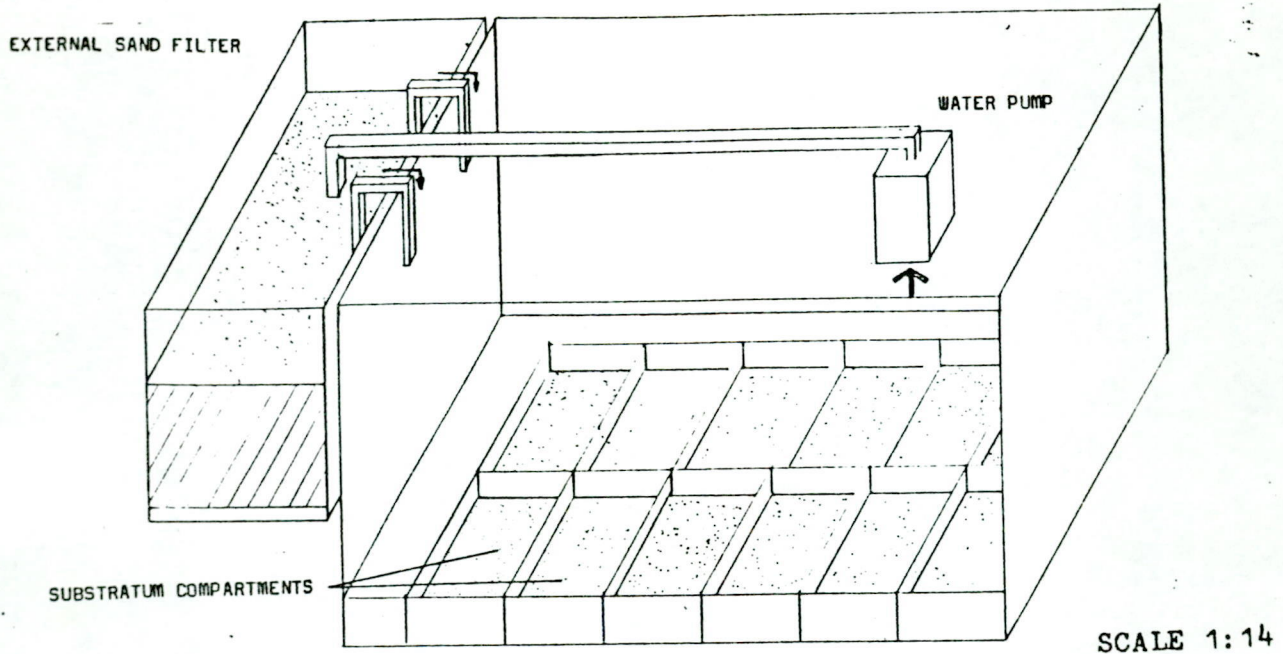


FIG. 2.

APPARATUS USED TO TEST SUBSTRATUM PREFERENCE OF *P. JAPONICUS*

The bottom of the test tank consisted of plastic trays dividing the tank into 12 compartments. Different substrata (Table 1) were placed in each compartment to a depth of 5 cm. A control tank was set up in the same way except medium sand was placed in all the compartments. The test tank and the control tank were interconnected via a filter system. This was to minimise variations in water quality between the two tanks. The effects of current flow were reduced by using short return siphons.

The prawns were fed before being used in the tests. Fifteen prawns of a single size range were placed into the test and control tanks and left overnight. The following day between 10h00 and 11h00 the prawns

were removed from the tanks. This was done by combing through the substratum with a wide-toothed comb, each compartment being done separately so that a record could be made of the number of prawns buried in each compartment. Recordings were made only when all fifteen prawns were fully submerged. This was replicated five times for each prawn size category. The positions of the various substrata were then changed and another five replicates were conducted.

An analysis of variance was then carried out on the data to test firstly that the prawns were showing no preference for a particular position in the tank and secondly to test that the preference for the various substrata was significant.

EXPERIMENT 2 - BURROWING TIME IN RELATION TO PARTICLE SIZE

Each of the 12 substratum grades (Table 1) was placed in a small glass tank which was filled with 10 cm of sea water. Ten prawns of each size class were then introduced to the tank. The time taken for four prawns to bury themselves was recorded. If more than ten minutes was required, then the time was taken to be infinite. Three replicates of each prawn size category was conducted for each substratum grade.

SUBSTRATUM ANALYSIS OF THE ST LUCIA SYSTEM

Substratum samples collected in 1982 were analysed in the following way. The sub-sieve particles (less than 63 μm) were removed by wet sieving in tap water. The remainder was oven dried at 105°C and sieved as for the

experimental substrata. The mean particle size of each sample was then calculated. These values together with mean particle sizes for the narrows calculated by van Heerden were then superimposed on an existing substratum map constructed by Cyrus in 1983.

SUBSTRATUM ANALYSIS OF DURBAN BAY

Sediment samples (4cm deep) were collected from the sand banks where *P. japonicus* were caught. These were analysed in the same manner as the St Lucia samples except the results were expressed as percentages of each of the twelve substratum grades used in the substratum preference tests.

why the diff?

RESULTS

Results of the substratum preferences of the small , medium , and large prawns are shown in fig. 3. The values are averages of ten replications of fifteen prawns.

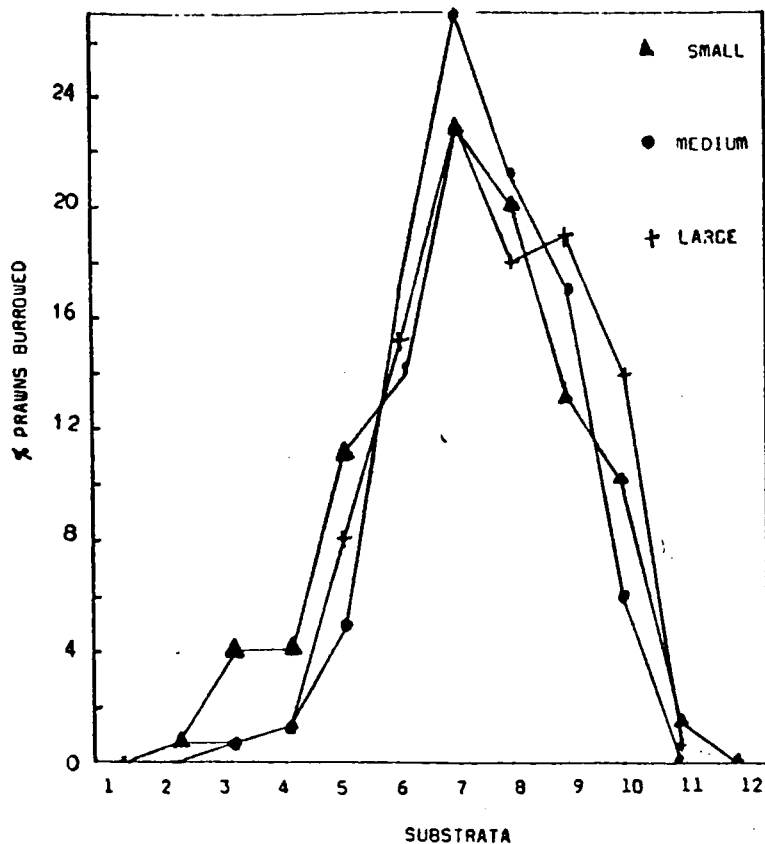


FIG. 3. Substratum choice of large, medium and small prawns. Showing no significant difference between the three sizes for substratum choice.

An analysis of variance was carried out on the data to test the following null hypotheses (h_0) at a confidence of $P = 0.001$.

h_0 1) The positions of the compartments in the control tank is having ^{no} a significant effect on the distribution of the prawns within the tank. (h_0)

Small prawns	F = 0.058	F(tab) = 3.6
Medium prawns	F = 0.228	F(tab) = 3.6
Large prawns	F = 0.608	F(tab) = 3.6

The null hypothesis was ~~rejected~~^{accepted} in all three prawn sizes. The prawns are therefore showing no preference for any particular section of the control tank

h_0 2) The different substrata presented to the prawns in the experimental tank are having no significant effect on the distribution of the prawns in the tank. (h_0)

Small prawns	F = 8.59	F(tab) = 3.0
Medium prawns	F = 21.69	F(tab) = 3.0
Large prawns	F = 17.9	F(tab) = 3.0

The null hypothesis was rejected in all three prawn sizes. The prawns are therefore showing a significant preference.

The time required for four large, medium, and small prawns to burrow into each substratum is shown in figs. 4,5,6. The values shown here are averages of three replicates of ten prawns for each grade of substratum. In addition to this the substrata choices of each prawn size is presented to facilitate comparisons.

Figs 7 & 8? Are these results?

Fig. 4 Time taken (seconds) for large prawns (carapace 18 - 25 mm) to burrow in a particular substratum.

7
% large prawns choosing a particular grade substratum.

Fig. 5 Time taken (seconds) for medium size prawns (carapace 10 - 17 mm) to burrow in a particular substratum.

% medium prawns choosing a particular grade substratum.

Fig. 6 Time taken (seconds) for small prawns (carapace 3 - 10 mm) to burrow into a particular substratum.

% small prawns choosing a particular grade substratum.

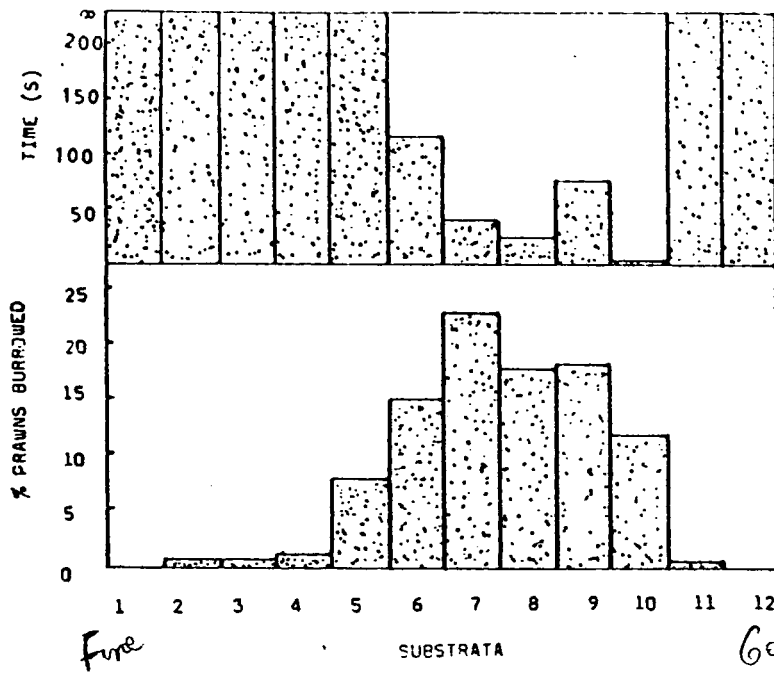


FIG. 4.

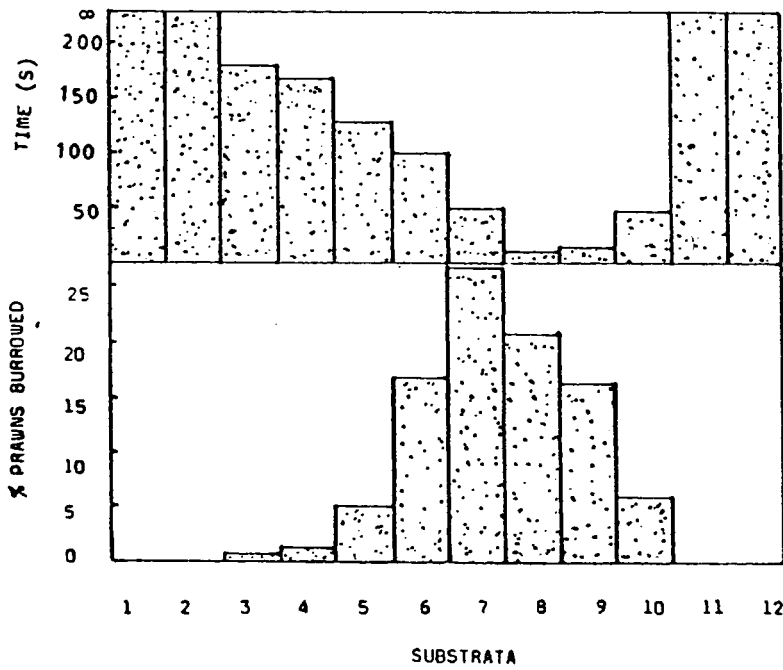


FIG. 5.

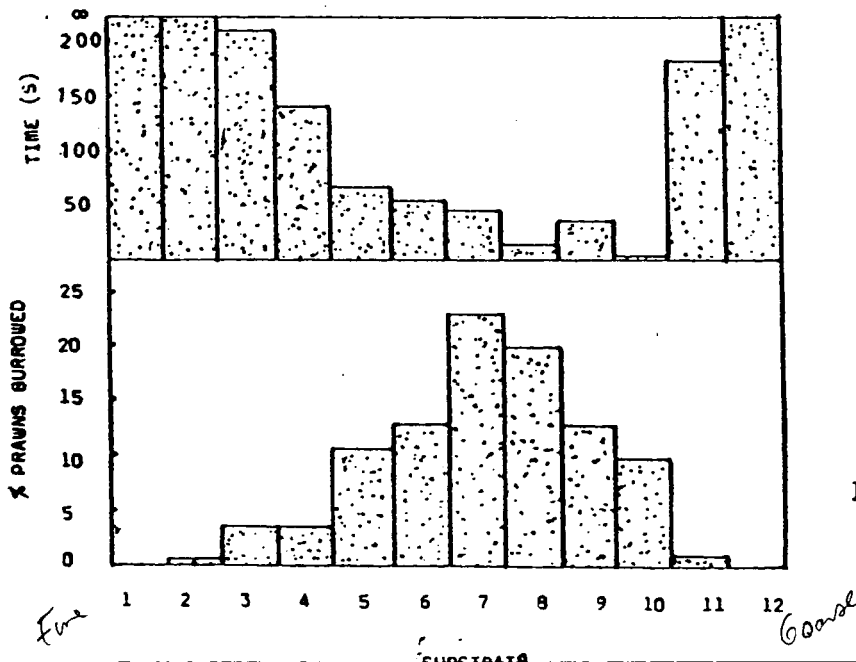
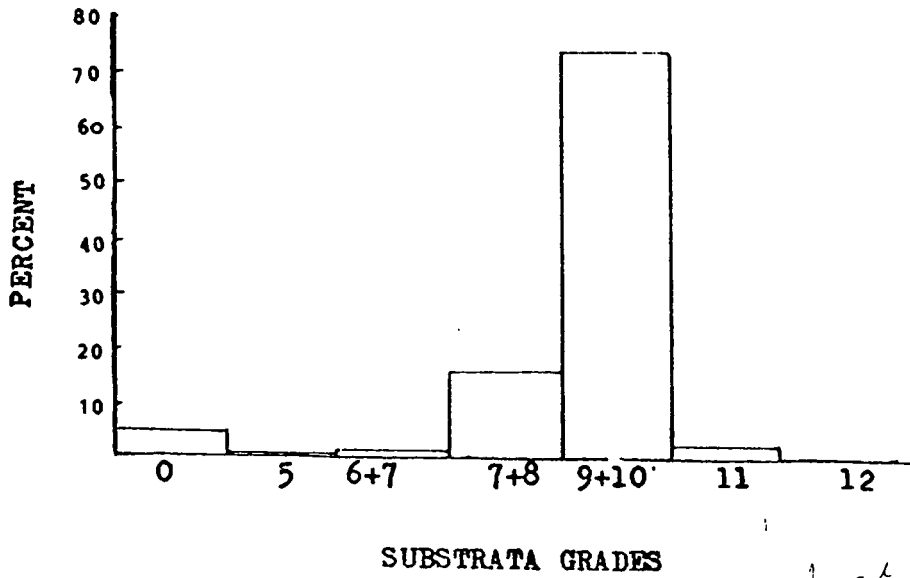


FIG. 6.



Why are some combined?

Fig. 7 Grades making up the Durban Bay sand.

ST LUCIA SYSTEM

Hluhluwe River

N.E. Shallows



Bird Island

Tewate Bay

Dead Tree Bay

Mpate River

KEY:

SITE	MEAN GRAIN SIZE (μm)	
1	32	
2	32	
3	17	
4	37	
5	28	
6	31	
7	65	
8	300	
9	200	
10	220	
11	150	13.2% silt
12	225	0.27% silt
13	63	23.4% silt
14	230	0.78% silt
15	63	100% silt
16	220	5.6% silt
17	240	10.7% silt
18	220	2.42% silt
19	270	1.7% silt
		 SAND
		 MUD

0 5 10 15 Km

FIG. 8

FIG. 8. Substratum map of the St Lucia system showing mean grain sizes and silt contents of several sampling sites. (data from Cyrus 1983 with modifications)

DISCUSSION

The findings of experiment one (Fig. 3) indicate that P. japonicus juveniles have a marked substratum preference with respect to particle size. For all three prawn sizes, the preferred particle size was in the range 355 - 500 μm . All three size categories of P. japonicus juveniles also showed a distinct avoidance of substrata with particles smaller than 180 μm . This was expected as particles smaller than 180 μm have very different physical properties to slightly larger particles. This is because very small particles exhibit particle - particle interactions which often cause them to aggregate. This occurs especially in clay minerals (Morgans 1956).

From observations made during the course of the experiment, it appeared that P. japonicus juveniles experienced difficulty in manipulating the larger particles indicating that this may be one of the factors limiting P. japonicus to finer substrata. P. japonicus however appears able to tolerate a much wider range of particles that are larger than the 'preferred' size range than they can particles smaller than the 'preferred' size.

P. japonicus juveniles have a distinctive burrowing technique which is better described as burying. This appears to be a predator avoidance behaviour. (De Freitas 1980) and involves fanning sediment particles backwards with the pleopods. This seems to indicate that the prawns' 'choice' of substratum may be a function of the speed and ease in which they are capable of burying themselves.

Figures 4, 5 and 6 compare the substratum preference of the prawns with those substrata that they could bury themselves fastest in. Although this so called 'optimum' particle size differs slightly between the three prawn sizes, there is a distinct relationship between it and the preferred substratum in all three cases. The findings of experiment 2 show that burying is accomplished fastest in substrata with particles between 180um and 250 um in diameter. This was expected as a particle of this size is regarded as the most mobile ^{Authority?} particle and would therefore be most suited to the mode of burying used by P. japonicus. The fact that the preferred particle size range does not correspond exactly with the 'optimum' size range suggests that there are some additional factors influencing the selection of substrata.

These may include clogging of the animals gills by very fine particles or the fact that a decrease in the particle size results in a decrease in permeability of the substratum to water. Since P. japonicus juveniles remain buried in the substratum for a large proportion of the time, a fine substratum would restrict the flow of water to the gills.

The substratum map of the St Lucia system (Fig. 8), although incomplete, shows a predominance of fine sand, very fine sand and silt. These are all substantially finer than the preferred substratum and in many cases fall into the category that was actively avoided by the prawns in experimental conditions. The only substratum in the St Lucia system that are close to the preferred substratum are found in a very narrow band that runs almost the entire length of the eastern shore.

Figure 2 shows a high silt content in a large proportion of the natural substrata that were analysed. Also, the St Lucia system is highly turbid with the result that silts and clays are very mobile in the system. (Cyrus 1983) Since P. japonicus showed an active avoidance of silt and the fact that there was a complete absence of silt in Durban bay which supports a relatively large population of P. japonicus (fig.3) it seems that the presence of silt in the substratum may be a significant factor reducing the survival of P. japonicus in St Lucia.

Although there are indications that other factors such as turbidity of the system and competition by other species which may be influencing the survival of P. japonicus, it does appear that substratum particle size is the major limiting factor in the St Lucia system.

Not bad at all.

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