POPULATION AND DISTRIBUTION OF MANGROVE PRAWNS AT THE KRANJI NATURE TRAIL ESTUARIES, WESTERN JOHOR STRAITS

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PROJECT REPORT

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Abstract

Six species of prawns are known to be the residents of mangroves at the study site: the snapping shrimps, *Alpheus euphrosyne* and *Alpheus microrhynchus*, the back mangrove shrimps, *Caridina propinqua*, *Potamalpheops tigger*, *Potamapheops johnsoni* and *Athanas polymorphus*. A baseline low tide map was produced in order to establish the study site for this and future study. The study was focused on the distribution of the *Alpheus* spp. Snapping sound generated by the enlarged claw of the shrimps was used as audio cue to detect the shrimps occurrence. Only one species of snapping shrimps, *A. euphrosyne*, was found in large number in this study. *A. euphrosyne* were patchily distributed as they were found in very specific parts of the study site. *C. propinqua* was found at area near to back mangrove, while *P. tigger*, *P. johnsoni* and *A. polymorphus* were found together at the sample site of *A. euphrosyne*.

(148 words)

INTRODUCTION

Mangrove is a unique environment established at estuaries, where freshwater and seawater mix. It supports wide diversity of fauna, serves as nursery and feeding grounds for fish and prawns (Berry, 1972; Sasekumar, 1992).

From a coastline almost entirely covered with mangroves in 18th century, the mangrove forest of Singapore now is found only in small patches, with the largest part of mangrove area at the northern part of main island and on Pulau Tekong, Pulau Ubin and Pulau Semakau. With development and industrialization, the total area of mangrove forest in Singapore has reduced dramatically from 13% in 1820's to 0.5% of the total land area (Sivasothi & Tan, 1999).

The flora and fauna of mangrove in Singapore are well-studied in terms of taxonomy and species richness and this is reflected by the presence of guidebooks of Singapore mangroves and various checklists of organisms. However, ecological studies of mangrove fauna is scarce, which poses an obstacle to sustainable management of mangrove.

Taxonomic studies on prawns by NUS and their visiting researchers, Peter Ng, Daisy Wowor, Darren Yeo, Cai Yi Xiong and Arthur Anker; have laid a good foundation to attempt ecological studies of mangrove prawns.

Kranji was selected as study site with the establishment of Kranji Nature Trail in 2002, which provides a safe and efficient access of the area. In the first part, a mapping project was conducted to produce a working low tide map of the research area for this and other studies.

In Singapore mangroves, the snapping sound of these shrimps is commonly heard but rarely seen. These shrimps appeared to occur in a specific sub-habitat in

earlier casual investigations (Sivasothi pers. comm.). The second part of this project thus investigated the distribution of mangrove snapping shrimps, *Alpheus* spp., and their populations examined.

MATERIALS AND METHODS

Part 1: Establishing a baseline low tide map defining the Kranji study site

This sub-project was conducted jointly by Teo Yen Ling and Fiona Hong over five mapping fieldtrips.

Materials

Measuring Tapes, 50m and 100m. Prismatic Compass, White Spray Paint, Flagging Tape, Clipboard, Pencil, A4 sheets, wooden poles.

Establishing the base and start points

The base and starting point are fixed points that will not disappear or be destroyed in the near future. The base point is additionally a known point that can be linked to a road map.

The stone marker commemorating the launch of the Kranji Nature Trail next to the SBWR carpark is the base point. The start point is the 3rd inner pillar of Bridge Two of Kranji Nature Trail.

Mapping in the field

Mapping is conducted as a measurement of distances and bearings of a series of straight lines by a data recorder and a surveyor. Starting out together at a fixed point, the surveyor decides the next point, and walks to it with one end of the measuring tape. This

is pulled taut and flushed directly with the midline of the body over the point, facing the recorder. The distance is read of in metres.

The recorder uses the compass to take the bearing to the surveyor, and records both values alongside a line indicating the relative position on a sketch map. An arrow head indicates the direction of the bearing. The approximate position of surrounding geographic features such as streams, streamlets, tree lines and bund is marked into the data sheet.

Precautions against confusion of data and inaccuracies during mapping include:

- Numbers are called out individually, e.g. 29.2 metres is called out as two-nine-point-two metres.
- The values called out by the surveyor is echoed by the recorder, and affirmed by surveyor.
- Distance and bearing are written with units next to the plotted lines.
- Pencil was used on paper for recordng data.
- White spray paint and flagging tapes were used to mark certain trees or points.
- The widths of streams are recorded at regular intervals. Meandering bends were indicated by recording the distance of the most pronounced section away from a point.
- The number of points used were minimized in order to avoid human error.
- Known, distinctly noticeable points were marked onto the map and served as additional reference points and tied back via mapping.
- Each session was reconnected back to the Starting Point in a circular manner.
- Fixed points or prominent markers were used as far as possible.
- Specific terms were used between workers:

- ‘Roll In’ – roll in measuring tape
- ‘Release’ – release end of measuring tape
- ‘Distance’ or ‘Bearing’ – to alert recorder or the surveyor to appropriate action before data is taken.

Plotting the data

Draft maps were prepared based on the fixed points after each mapping session using the data, a protractor and a ruler, on a scale of 1:1000. These draft maps included the bearing arrows, distances and bearings (see Appendix I). When loop backs of straight lines did not reconnect to the start point on paper, remapping was conducted in the field.

The completed draft map was drawn on A3 paper. The map was inked with waterproof and fade-proof ink on tracing paper placed above the draft sheet. Tree-line, streams, markers and other recorded features were drawn in using another sheet of tracing paper. The final draft was inked on an additional layer of tracing paper. Appropriate labelling (labels, legend, north arrow) was added, and the resultant map was photocopied onto paper and scaled to size.

Part II: Investigation on the distribution of mangrove prawns

Sampling Methods

A total of 14 sampling fieldtrips were carried out in two months, starting from 18/1/04 to 18/3/04. During visits to study site, the researcher, together with student volunteers from National University of Singapore and Mr. Sivasothi, examined the distribution of prawns, and made counts of the numbers of prawns found.

Survey of mangrove prawn distributions

In the beginning, point-search samplings were conducted at different sub-habitats of field site. Different methods, in different habitats were employed to familiarize the researcher. A fish net with mesh size 1.5 mm was used to catch shrimps in the streams, streamlets and stagnant water pools. At specific micro-habitats such as water pools sheltered by rotting logs or wood planks, the covers were turned over and water was disturbed by hands and shrimps detected by movement. The small shrimps were obtained by sieving through the water and mud carefully. Even smaller shrimps were obtained with a 1.0 mm mesh sized-sieve.

Sampling for the snapping shrimps

The fifth and subsequent fieldtrips focused on the sampling the snapping shrimps. Popping sound generated by the modified giant claw of snapping shrimps was used as an indication of its occurrence. During the fifth sampling fieldtrip (13/2/03), together with research supervisor, Mr Sivasothi, the area of Buloh East Channel was examined to find the snapping shrimps. A sheltered area with contoured ground and very shallow streamlet flowing through was thought to have a reasonably frequent

snapping sounds (Sivasothi, pers. comm.). An approximate area of 4 m^2 was searched by digging out the surface layer of mud and detecting movement. Snapping shrimps were collected by hand when detected as they crawled or swam.

Subsequently, other areas were searched for these audio cue - the snapping sound generated by the snapping shrimps in the mud. Quadrats were set up when popping sounds was heard in a specific area. During the 5^{th}-11^{th} fieldtrip, 4 m^2 quadrats were set up and extended in straight line perpendicular across the river or stream up to the other bank. This allowed heterogeneous sub- to be surveyed. Bearings and distances of the quadrats were recorded. Each quadrat sample was labelled A - R.

Sub-habitats were described by water flow, substrate, exposure and water salinity. Salinity was measured in percentage using a refractormeter. All observation was recorded onto a sketch map of research site. The temperature of the water surface and mud were taken at the muddy beach at KR3 (exposed to direct sunlight) and sheltered area at Buloh East Channel during the 13^{th} sampling fieldtrip..

Tiny mangrove prawns

Apart from *Alpheus* sp., some tiny mangrove prawns (up to 15 mm) were observed in these sample sites. Water channels were created by digging up the mud to create barriers and dams. Movement of organisms was detected in the directed, moving water and collected. Small prawns were caught using the cover-cap of vials, which were gently tilted into the flowing water near the shrimps. The shrimps were quickly scoped up with the water transferred into the vials. During the last fieldtrip session, a sieve was used to collect the tiny shrimp but the sticky mud does not facilitate easy sieving.

Saturation sampling

During the last three sampling sessions (12th to 14th fieldtrip), one quadrat was set up and a saturation search was conducted within the quadrat. Prawns were carefully searched by digging up the top layer of mud thoroughly. The search only ended when no shrimps were detected despite considerable disturbance.

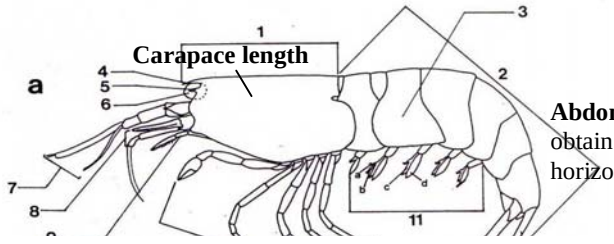
Preservation, measurement and identification

Prawns were kept alive in zip-lock bag, vials or plastic boxes filled with mud or brackish water from the same site. The prawns were washed clean in the laboratory and subsequently killed by low temperature in freezer and transferred into alcohol 75% for preservation. For *Alpheus euphrosyne*, due to large number of shrimps available, some were kept alive for release during the subsequent fieldtrips.

The gender and the side of enlarged claw of the snapping shrimps were noted and recorded. Measurements of carapace and total length of snapping shrimps were taken using calipers (see Fig. 1):

Total length = tip of the rostrum to the distal margin of the telson

Carapace length = anterior margin of the orbital hood to the dorsal posterior margin of the carapace in lateral view



Abdomen, straighten to obtain total length horizontally

Figure 1: Adult Alpheid shrimp in lateral view. Yeo D. C. J. (1996)

After preservation, the species of prawns collected are identified based on the key described by Holthuis (1996) for caridean shrimps, Yeo & Ng (1997) for the snapping shrimps and Anker (2003) for other Alpheid shrimps and *Athanas* spp.

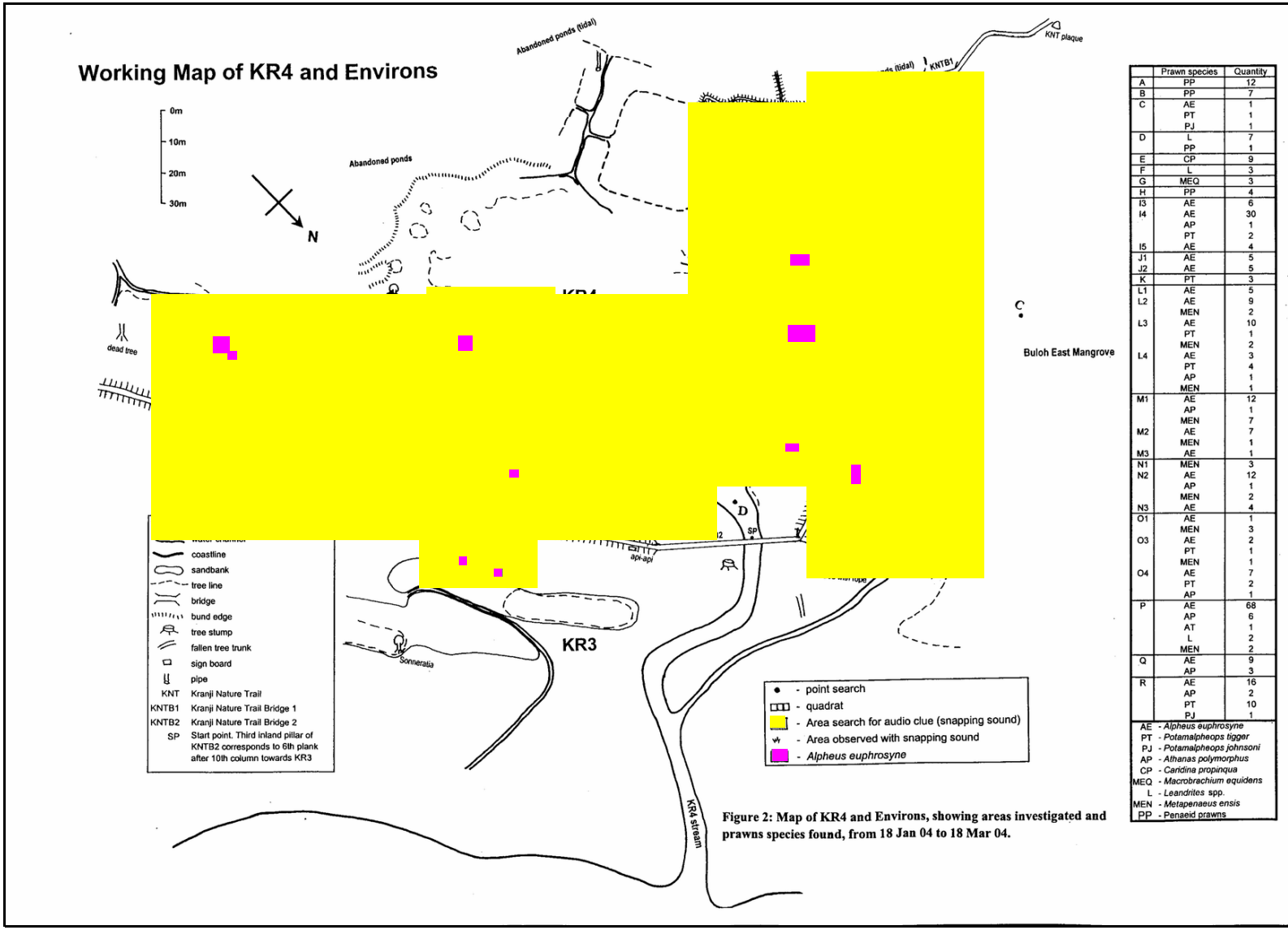
RESULTS

Mangrove Prawn distribution

The results are shown in Figure 2.

Table 1: Number of prawns observed per topography site by species, from 18 Jan 2004 to 18 Mar 2004. Species: AE, *Alpheus euphrosyne*; PT, *Potamalpheops tigger*; PJ, *Potamalpheops johnsoni*; AP, *Athanas polymorphus*; CP, *Caridina propinqua*; MEQ; *Macrobrachium equidens*; PP, penaeid prawns; MEN, *Metapenaeus ensis*, L, *Leandrites* spp.

Topography Feature	AE	PT	PJ	AP	CP	MEQ	PP	MEN	L
mangrove platform	201	22	3	14	0	0	0	19	2
hyposaline stream	0	0	0	0	9	3	0	0	0
stream bank	16	3	1	0	0	0	0	5	0
stream	0	0	0	0	0	0	20	0	10



	Prawn species	Quantity
A	PP	12
B	PP	7
C	AE	1
	PT	1
	PJ	1
D	L	7
	PP	1
E	CP	9
F	L	3
G	MEQ	3
H	PP	4
I3	AE	6
I4	AE	30
	AP	1
	PT	2
I5	AE	4
J1	AE	5
J2	AE	5
K	PT	3
L1	AE	5
L2	AE	9
	MEN	2
L3	AE	10
	PT	1
	MEN	2
L4	AE	3
	PT	4
	AP	1
	MEN	1
M1	AE	12
	AP	1
	MEN	7
M2	AE	7
	MEN	1
M3	AE	1
N1	MEN	3
N2	AE	12
	AP	1
	MEN	2
N3	AE	4
O1	AE	1
	MEN	3
O3	AE	2
	PT	1
	MEN	1
O4	AE	7
	PT	2
	AP	1
P	AE	68
	AP	6
	AT	1
	L	2
	MEN	2
Q	AE	9
	AP	3
R	AE	16
	AP	2
	PT	10
	PJ	1

AE - *Alpheus euphrosyne*
PT - *Potamalpheops tigger*
PJ - *Potamalpheops johnsoni*
AP - *Athanas polymorphus*
CP - *Caridina propinqua*
MEQ - *Macrobrachium equidens*
L - *Leandrites* spp.
MEN - *Metapenaeus ensis*
PP - Penaeid prawns

Figure 2: Map of KR4 and Environs, showing areas investigated and prawns species found, from 18 Jan 04 to 18 Mar 04.

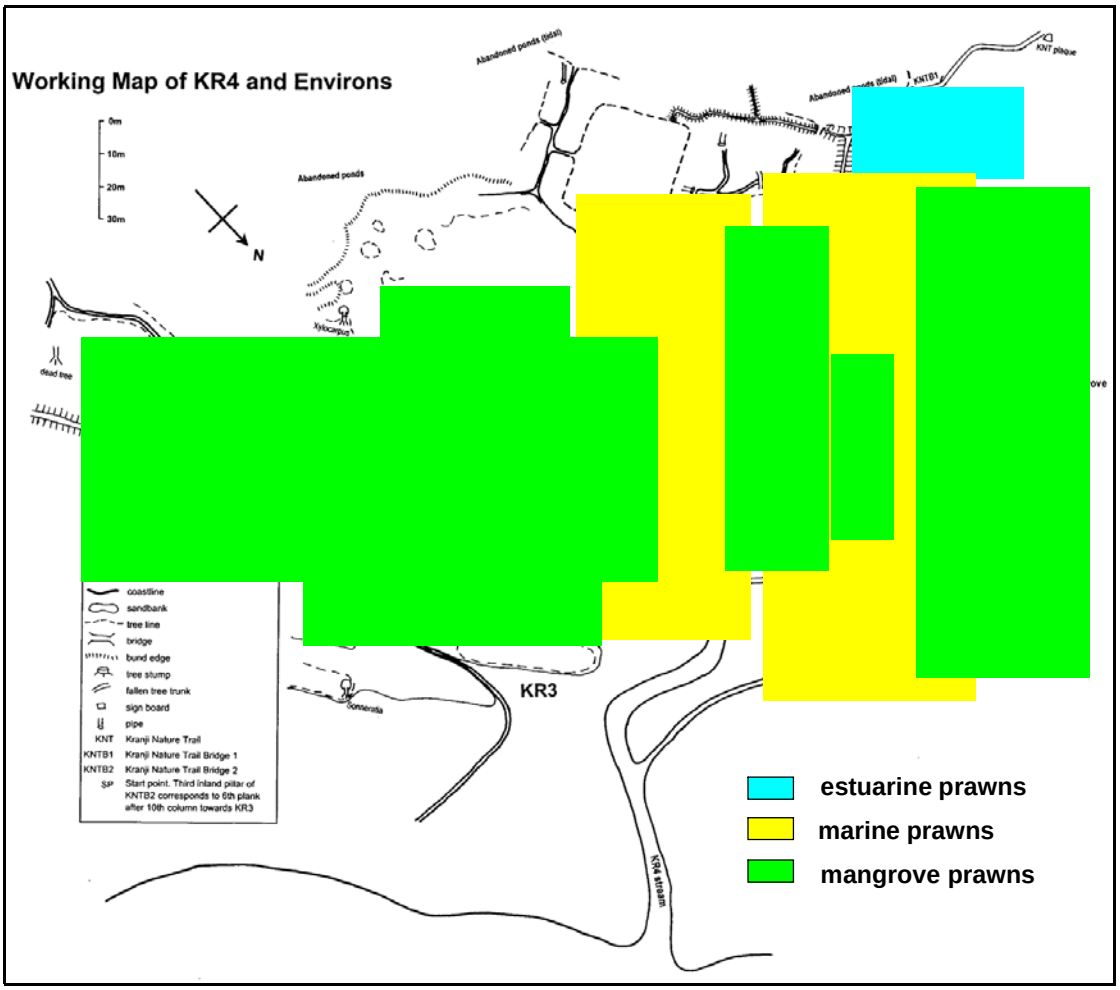


Figure 3: Approximate distribution of mangrove prawns in Kranji research site, from 18 Jan 2004 to 18 Mar 2004

The *Alpheus euphrosyne* population

Gender distribution

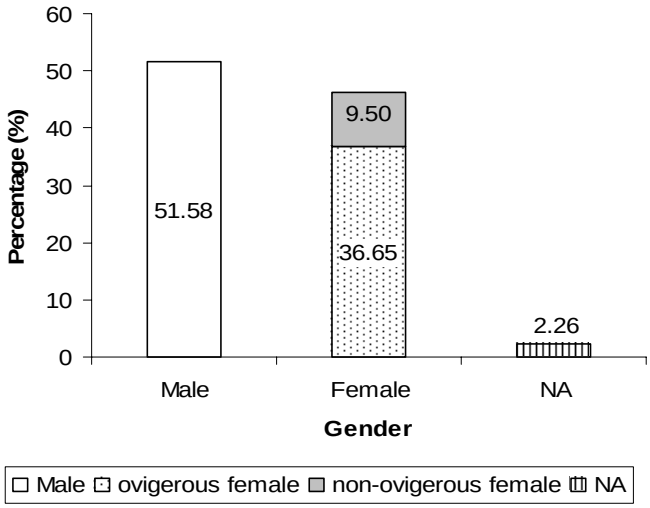


Figure 4: Gender of *Alpheus euphrosyne* collected, from 18 Jan 2004 to 18 Mar 2004. (NA, not available due to absent of first smaller leg.)

The ratio of male *Alpheus euphrosyne* to female *Alpheus euphrosyne* = 1.12.

The proportion of ovigerous female *Alpheus euphrosyne* = 79.41% of all female

Plate 1: Ovigerous female *Alpheus euphrosyne*

Side of giant modified claw

Out of 221 specimens collected, 6 prawns were not used due to the absence of both first pairs of leg. Of the remaining 215 specimens, 53.02% of *Alpheus euphrosyne* had a right giant claw while 43.98% had a left giant claw. The ratio of right to left giant claw is 1.13.

Plate 2: *Alpheus euphrosyne* with right (A) and left (B) side giant modified claw

Size of *Alpheus euphrosyne*

The size of *Alpheus euphrosyne*, by gender is illustrated in figure 5.

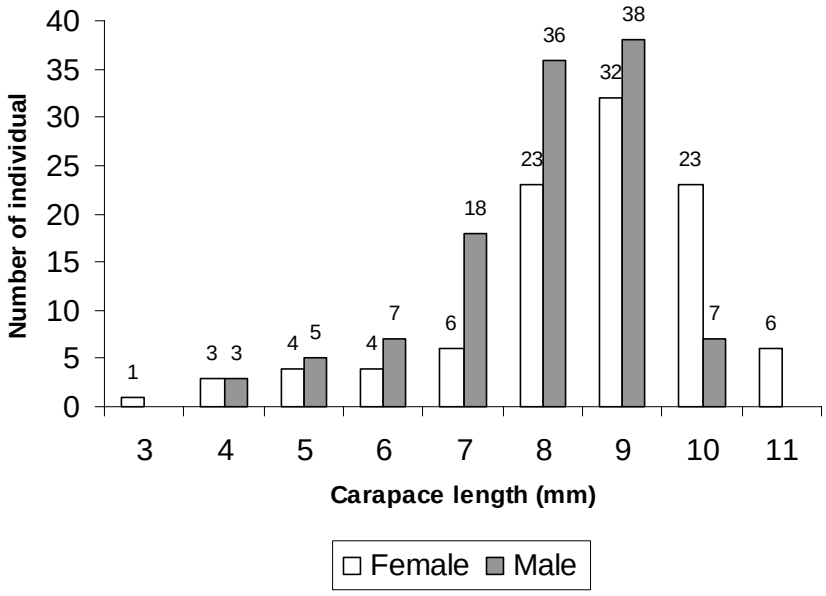


Figure 5: Size of *Alpheus euphrosyne* by gender.

DISCUSSION

Part 1: Establishing the map of the study site

Map of the area were out-dated or not accessible. A map is required to establish the study site to show the complex topography in mangroves, which contain sub-habitat and possibly numerous niches. Besides, map is a useful tool to determine distribution patterns of flora and fauna of the mangroves. The current map can be a template on which future distribution studies can be conducted. Photos and figures of the map will be archived at the Mangroves of Singapore webpage at: http://mangrove.nus.edu.sg

Prawn species found in mangroves

The species of prawns encountered in the study site can be divided into two categories: non-residents and residents.

The non-resident prawns are mostly juveniles, as adults live in more open waters. Mangroves thus serve as nursery ground (Daisy Wowor, pers.comm.). These were subdivided further into marine and estuarine prawns. Marine prawns included Penaiede prawns (e.g. *Metapenaeus ensis*), and other caridean prawns (*Leandrites* sp.). The estuarine prawn (*Macrobrachium equidens*) was found at the hyposaline stream at the study site, although the juvenile of this species is scattered through out the channel.

True residents include the snapping shrimp (*Alpheus euphrosyne* & *A. microrhyncus),* the back mangrove prawns (*Caridina propinqua),* the two recently reported new species (*Potamalpheops tigger* (Yeo & Ng, 1997) & *P. johnsoni* (Anker, 2003)), and the first *Athanas* sp. reported in Singapore, *A. polymorphus* (Anker, 2003).

Non-resident prawns species in mangroves

Macrobrachium equidens is a common estuarine prawn found in Singapore. The juvenile of this species is present in the shallow water pools and streams throughout the Buloh East Channel. The ovigerous female *M. equidens* were found in the deep water pool up-stream of the channel, with 21% water salinity. This suggests that the adult female *M. equidens* spawn in the mangrove.

Penaeid prawns and *Leandrites* spp. were observed swimming in streams and pools. Most of these prawns are small in size and caught in clusters, suggesting that the juveniles grow up in mangroves. The actual species of the penaeid prawns and *Leandrites* genus were not identified due to unfamiliarity and complexity of the subject.

One species could be identified. *Metapenaeus ensis*, a penaeid prawn, was found together with *Alpheus euphrosyne* at the muddy area in the mangrove platform. Juveniles of these prawns are commonly found in estuaries and backwaters, mangrove banks and mud flat (Carpenter & Niem, 1998).

Resident prawns species in mangroves

Figure 3 indicates the distribution of prawns in the study site. Generally, resident mangrove species were found in the muddy area of mangrove platforms except *Caridina propinqua*. *C. propinqua* was found in the shallow upper stream near the back mangrove area, where water salinity was 21%, relatively less than the lower stream area. These tiny prawns were caught by using small mesh size fish net.

The other resident mangrove prawns, *Alpheus euphrosyne*, *Potamalpheops tigger*, *P. johnsoni* and *Athanas polymorphus*, were found in relative abundance in the mud of the mangrove platform. These shrimps were absent from the stream and open

water area. Although they were found in one of the sampling sites at the stream bank, they were in much fewer numbers.

Potamalpheops tigger, *P. johnsoni* and *Athanas polymorphus* deserve special mention. They are tiny shrimps with total body length of 10-15 mm, and were found together with *A. euphrosyne*. *P. tigger* and *A. polymorphus* were found in almost all every study site. *P. johnsoni* was the rarest, with only three individuals found throughout the study.

Eight out of 15 *A. polymorphus* was found in the study site exposed to sunlight and nearer the sea.

15 out of 20 *P. tigger* were found in sheltered areas, either by the canopy of the mangrove or by dead logs and wood planks.

Two small prawns remain unidentified at the present time despite consultation with taxonomists.

Despite its large size, *Alpheus microrhyncus* was not found throughout the study. These shrimps were reported from Sungei Buloh mangrove in 1995 (Yeo, 1996). However, it is very difficult to collect as this large snapping shrimp tends to burrow very deeply into soft mud (D. Yeo, pers. comm.).

Figure 3 indicates the distribution of prawns. A distribution pattern for prawns begins to emerge. Non-resident estuarine prawns and *Caridina propinqua*, are found in the hyposaline area towards the back mangrove. Non-resident marine prawns are found in the stream and open water bodies. Resident mangrove prawns dominate the mangrove platform.

Sampling methods for the snapping shrimps

The popping sound of snapping shrimps was always heard, but rarely seen. Taxonomists suggest that these shrimps burrow deeply and are difficult to find. However, the results of this study has proven that *A. euphrosyne* can be easily detected by the snapping sound. The sound intensity varies in different areas, which suggests it could be used as an indicator of population size. A proper method to measure the sound intensity should be established and correlated in a future study.

Distribution and sub-habitats of *Alpheus euphrosyne*

Alpheus euphrosyne were patchily distributed as they were found in very specific parts of the study site. Two sampling sites, site I and P, were found to have very high numbers of *A. euphrosyne* (see figure 2 and plate 3). Both sites were observed to have similar topography shown in figure 6 below:

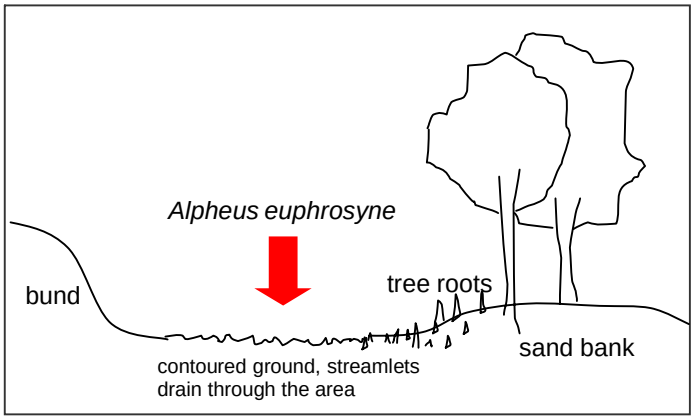


Figure 6: Topography pattern of sub-habitat of *Alpheus euphrosyne*
based on observed from the high density population sample site, site I and P

Plate 3: contoured ground and sand bank at site I, where large number of *Alpheus euphrosyne* found

The sub-habitat shown suggests that *Alpheus euphrosyne* favours the contoured muddy areas with slow flowing streamlets during low tide. The adjacent bund and sandbank creates a low platform which is damp with water. The area is unaffected by sunlight as one area was exposed and another exposed. The prawns are able to burrow in the contoured ground to take shelter from the sun.

Sexual maturity of *Alpheus euphrosyne*

The gender of *Alpheus euphrosyne* was determined by observing the smaller claw of the first leg of the prawns, with male having a layer of hairs at the chela absent in the female. 2.26% of *A. euphrosyne* could not be sexed due to the absence of the first smaller leg. However, out of 221 specimens collected, 51.58% were male and 46.15% female. The ratio of male to female is 1.12.

Of 102 female *A. euphrosyne*, 79.41% were gravid, with the smallest ovigerous female observed to be 6 mm in carapace length. This suggests that the presence of hairs on males may not reflect sexual maturity, although it used to separate the genders. More specimens of small-sized *A. euphrosyne* are needed to confirm this conclusion.

The giant modified claw of snapping shrimps develop randomly either on left or right side with the normal ratio of right to left enlarged claw at one. In this study, the ratio was 1.14, with 53.02% and 46.98% of *A. euphrosyne* armed with right and left enlarged claw respectively.

In a distribution of class sizes, both female and male were most numerous in size class 9 mm (see Figure 5). However, there were more females *A. euphrosyne* in the larger size classes of 10 and 11 mm carapace length. This result suggests that the female *A. euphrosyne* of the same age are larger than male.

Out of 221 specimens collected, three *Alpheus euphrosyne* were found without rostrum. This might be deformation or newly-moulted prawns (D. Yeo, pers. comm.). However, the actual reasons are uncertain.

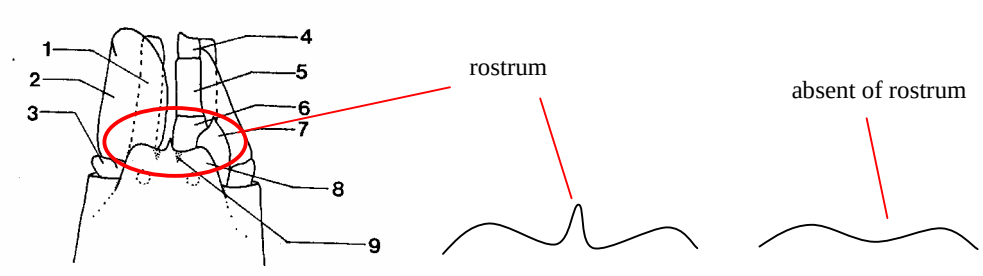


Figure 7: Anterior drawing of an *Alpheus* shrimp in dorsal view. Yeo (1996), showing normal specimen with rostrum and without rostrum

Conclusion

Alpheus euphrosyne appeared to colonize specific sub-habitat in mangrove, with the highest number of these shrimps discovered at the sites bordered by bund, sandbank, and contoured ground. Large number of *A. euphrosyne* found in this study showed that the selection of sampling site are critical and important. Snapping sound was used in this study as the indicator of *A. euphrosyne* population. However, the specific sub-habitat of *A. euphrosyne* is yet to determine.

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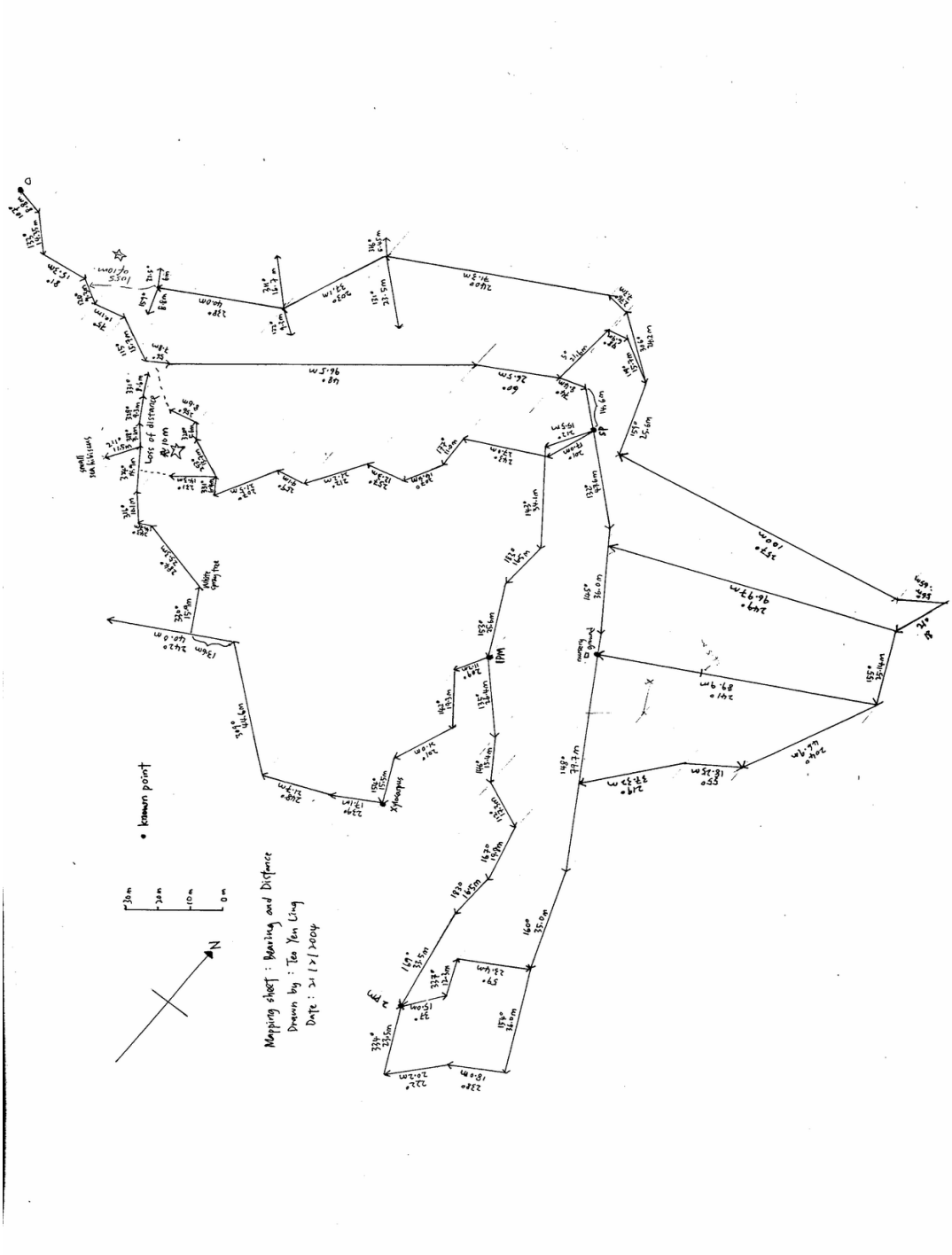
Appendix 1

Figure 8: Draft maps included the bearing arrows, distances and bearings of study site



Appendix 1I

Plate 4: Point search, showing researchers using fish net and observing prawns in streamlet

Plate 5: On-site measurement, taking carapace length of *Alpheus euphrosyne*

Appendix III

Table 2: Morphomatrix data of *Alpheus euphrosyne* collected, from 1 Jan 2004 to 18 Mar 2004

Sample site	Location	Salinity (%)	Overstorey cover	Gender	Giant claw (Right/ Left)	Carapace length (mm)	Total length (mm)
C	Buloh east channel	NA	sheltered	OF	NA	9	30
I3	Buloh east channel	26%	sheltered	F	NA	8	29
I3	Buloh east channel	26%	sheltered	M	L	7	23
I3	Buloh east channel	26%	sheltered	M	R	8	26
I3	Buloh east channel	26%	sheltered	OF	L	8	26
I3	Buloh east channel	26%	sheltered	OF	L	8	25
I3	Buloh east channel	26%	sheltered	OF	R	10	34
I4	Buloh east channel	26%	sheltered	F	L	9	27
I4	Buloh east channel	26%	sheltered	F	R	10	32
I4	Buloh east channel	26%	sheltered	F	R	11	31
I4	Buloh east channel	26%	sheltered	J	R	3	10
I4	Buloh east channel	26%	sheltered	M	L	8	24
I4	Buloh east channel	26%	sheltered	M	L	8	27
I4	Buloh east channel	26%	sheltered	M	L	9	26
I4	Buloh east channel	26%	sheltered	M	L	9	27
I4	Buloh east channel	26%	sheltered	M	L	9	28
I4	Buloh east channel	26%	sheltered	M	L	9	28
I4	Buloh east channel	26%	sheltered	M	L	9	28
I4	Buloh east channel	26%	sheltered	M	L	9	29
I4	Buloh east channel	26%	sheltered	M	L	9	31
I4	Buloh east channel	26%	sheltered	M	R	8	23
I4	Buloh east channel	26%	sheltered	M	R	8	25
I4	Buloh east channel	26%	sheltered	M	R	8	26
I4	Buloh east channel	26%	sheltered	M	R	9	29
I4	Buloh east channel	26%	sheltered	M	R	9	27
I4	Buloh east channel	26%	sheltered	M	R	9	27
I4	Buloh east channel	26%	sheltered	M	R	9	27
I4	Buloh east channel	26%	sheltered	M	R	10	28
I4	Buloh east channel	26%	sheltered	OF	L	9	28
I4	Buloh east channel	26%	sheltered	OF	L	9	27
I4	Buloh east channel	26%	sheltered	OF	L	9	30
I4	Buloh east channel	26%	sheltered	OF	L	10	29
I4	Buloh east channel	26%	sheltered	OF	R	9	27
I4	Buloh east channel	26%	sheltered	OF	R	10	30
I4	Buloh east channel	26%	sheltered	OF	R	10	31
I4	Buloh east channel	26%	sheltered	OF	R	10	32
I4	Buloh east channel	26%	sheltered	OF	R	10	32
I5	Buloh east channel	26%	sheltered	F	NA	8	26
I5	Buloh east channel	26%	sheltered	M	R	9	24
I5	Buloh east channel	26%	sheltered	M	R	9	27
I5	Buloh east channel	26%	sheltered	OF	NA	11	32
J1	KR4 West	27%	sheltered	M	L	8	29
J1	KR4 West	27%	sheltered	M	R	10	32
J1	KR4 West	27%	sheltered	MJ	R	5	15
Sample site	Location	Salinity (%)	Overstorey cover	Gender	Giant claw (Right/ Left)	Carapace length (mm)	Total length (mm)

J1	KR4 West	27%	sheltered	OF	L	9	32
J1	KR4 West	27%	sheltered	OF	L	10	33
J2	KR4 West	27%	sheltered	F	R	6	20
J2	KR4 West	27%	sheltered	M	L	8	24
J2	KR4 West	27%	sheltered	M	R	9	29
J2	KR4 West	27%	sheltered	OF	R	10	32
J3	KR4 West	27%	sheltered	M	R	9	29
L1	KR4 West	24%	sheltered	J	L	4	13
L1	KR4 West	24%	sheltered	J	NA	5	15
L1	KR4 West	24%	sheltered	M	L	9	30
L1	KR4 West	24%	sheltered	M	L	9	29
L1	KR4 West	24%	sheltered	OF	R	10	34
L2	KR4 West	24%	sheltered	M	L	8	27
L2	KR4 West	24%	sheltered	M	L	8	28
L2	KR4 West	24%	sheltered	M	L	9	26
L2	KR4 West	24%	sheltered	M	R	7	29
L2	KR4 West	24%	sheltered	M	R	9	28
L2	KR4 West	24%	sheltered	OF	L	9	31
L2	KR4 West	24%	sheltered	OF	L	9	30
L2	KR4 West	24%	sheltered	OF	L	10	33
L2	KR4 West	24%	sheltered	OF	R	8	29
L3	KR4 West	24%	sheltered	J	L	3	9
L3	KR4 West	24%	sheltered	M	L	9	31
L3	KR4 West	24%	sheltered	M	L	9	32
L3	KR4 West	24%	sheltered	M	R	6	20
L3	KR4 West	24%	sheltered	M	R	7	27
L3	KR4 West	24%	sheltered	M	R	9	28
L3	KR4 West	24%	sheltered	M	R	10	33
L3	KR4 West	24%	sheltered	OF	R	9	30
L3	KR4 West	24%	sheltered	OF	R	10	32
L3	KR4 West	24%	sheltered	OF	R	11	36
L4	KR4 West	24%	sheltered	M	L	8	25
L4	KR4 West	24%	sheltered	M	R	7	25
L4	KR4 West	24%	sheltered	OF	R	6	27
M1	KR4 West	25%	sheltered	M	L	7	27
M1	KR4 West	25%	sheltered	M	L	8	25
M1	KR4 West	25%	sheltered	M	L	9	30
M1	KR4 West	25%	sheltered	M	R	7	26
M1	KR4 West	25%	sheltered	M	R	8	25
M1	KR4 West	25%	sheltered	M	R	9	29
M1	KR4 West	25%	sheltered	M	R	9	28
M1	KR4 West	25%	sheltered	MJ	L	4	14
M1	KR4 West	25%	sheltered	MJ	L	5	15
M1	KR4 West	25%	sheltered	OF	R	8	29
M1	KR4 West	25%	sheltered	OF	R	10	33
M1	KR4 West	25%	sheltered	OF	R	11	34
M2	KR4 West	25%	sheltered	J	NA	4	12
M2	KR4 West	25%	sheltered	M	L	6	20

Sample site	Location	Salinity (%)	Overstorey cover	Gender	Giant claw (Right/ Left)	Carapace length (mm)	Total length (mm)
M2	KR4 West	25%	sheltered	M	L	7	27
M2	KR4 West	25%	sheltered	M	R	8	27
M2	KR4 West	25%	sheltered	OF	L	9	31

M2	KR4 West	25%	sheltered	OF	L	9	33
M2	KR4 West	25%	sheltered	OF	R	11	32
M3	KR4 West	NA	sheltered	OF	R	9	29
N2	KR4 East	23%	exposed	F	R	10	32
N2	KR4 East	23%	exposed	FJ	L	3	7
N2	KR4 East	23%	exposed	FJ	R	5	16
N2	KR4 East	23%	exposed	FJ	R	5	16
N2	KR4 East	23%	exposed	M	L	9	32
N2	KR4 East	23%	exposed	M	R	7	27
N2	KR4 East	23%	exposed	MJ	L	4	12
N2	KR4 East	23%	exposed	MJ	R	4	14
N2	KR4 East	23%	exposed	OF	L	9	26
N2	KR4 East	23%	exposed	OF	L	9	29
N2	KR4 East	23%	exposed	OF	R	7	26
N2	KR4 East	23%	exposed	OF	R	8	30
N3	KR4 East	23%	exposed	M	L	8	29
N3	KR4 East	23%	exposed	M	L	9	28
N3	KR4 East	23%	exposed	OF	L	7	27
N3	KR4 East	23%	exposed	OF	R	9	28
O1	KR4 East	24%	sheltered	M	R	6	24
O3	KR4 East	24%	sheltered	F	L	9	30
O3	KR4 East	24%	sheltered	M	R	10	32
O4	KR4 East	24%	sheltered	F	L	10	30
O4	KR4 East	24%	sheltered	M	L	9	31
O4	KR4 East	24%	sheltered	M	R	8	28
O4	KR4 East	24%	sheltered	M	R	10	30
O4	KR4 East	24%	sheltered	OF	L	8	28
O4	KR4 East	24%	sheltered	OF	L	9	31
O4	KR4 East	24%	sheltered	OF	R	10	32
P	KR3	27%	exposed	F	L	8	24
P	KR3	27%	exposed	F	L	9	26
P	KR3	27%	exposed	FJ	L	4	10
P	KR3	27%	exposed	FJ	R	4	12
P	KR3	27%	exposed	FJ	R	4	11
P	KR3	27%	exposed	FJ	R	5	15
P	KR3	27%	exposed	M	L	6	21
P	KR3	27%	exposed	M	L	7	21
P	KR3	27%	exposed	M	L	7	21
P	KR3	27%	exposed	M	L	7	23
P	KR3	27%	exposed	M	L	7	23
P	KR3	27%	exposed	M	L	7	23
P	KR3	27%	exposed	M	L	7	23
P	KR3	27%	exposed	M	L	8	23
P	KR3	27%	exposed	M	L	8	24
P	KR3	27%	exposed	M	L	8	26

Sample site	Location	Salinity (%)	Overstorey cover	Gender	Giant claw (Right/ Left)	Carapace length (mm)	Total length (mm)
P	KR3	27%	exposed	M	L	8	26
P	KR3	27%	exposed	M	L	8	25
P	KR3	27%	exposed	M	L	8	28
P	KR3	27%	exposed	M	L	9	27
P	KR3	27%	exposed	M	L	9	27
P	KR3	27%	exposed	M	R	6	20

P	KR3	27%	exposed	M	R	7	23
P	KR3	27%	exposed	M	R	7	23
P	KR3	27%	exposed	M	R	7	24
P	KR3	27%	exposed	M	R	7	24
P	KR3	27%	exposed	M	R	8	23
P	KR3	27%	exposed	M	R	8	25
P	KR3	27%	exposed	M	R	8	24
P	KR3	27%	exposed	M	R	8	24
P	KR3	27%	exposed	M	R	8	24
P	KR3	27%	exposed	M	R	8	25
P	KR3	27%	exposed	M	R	8	24
P	KR3	27%	exposed	M	R	8	25
P	KR3	27%	exposed	M	R	8	26
P	KR3	27%	exposed	M	R	8	25
P	KR3	27%	exposed	M	R	8	26
P	KR3	27%	exposed	M	R	9	27
P	KR3	27%	exposed	M	R	9	26
P	KR3	27%	exposed	M	R	9	27
P	KR3	27%	exposed	MJ	L	5	15
P	KR3	27%	exposed	OF	L	7	24
P	KR3	27%	exposed	OF	L	8	25
P	KR3	27%	exposed	OF	L	8	26
P	KR3	27%	exposed	OF	L	8	25
P	KR3	27%	exposed	OF	L	8	27
P	KR3	27%	exposed	OF	L	9	28
P	KR3	27%	exposed	OF	L	9	27
P	KR3	27%	exposed	OF	L	9	28
P	KR3	27%	exposed	OF	L	9	28
P	KR3	27%	exposed	OF	L	10	30
P	KR3	27%	exposed	OF	L	10	29
P	KR3	27%	exposed	OF	R	6	22
P	KR3	27%	exposed	OF	R	7	23
P	KR3	27%	exposed	OF	R	7	23
P	KR3	27%	exposed	OF	R	7	23
P	KR3	27%	exposed	OF	R	8	25
P	KR3	27%	exposed	OF	R	8	24
P	KR3	27%	exposed	OF	R	8	27
P	KR3	27%	exposed	OF	R	8	27
P	KR3	27%	exposed	OF	R	8	24
P	KR3	27%	exposed	OF	R	8	27
P	KR3	27%	exposed	OF	R	8	26
P	KR3	27%	exposed	OF	R	9	27

Sample site	Location	Salinity (%)	Overstorey cover	Gender	Giant claw (Right/ Left)	Carapace length (mm)	Total length (mm)
P	KR3	27%	exposed	OF	R	9	27
P	KR3	27%	exposed	OF	R	9	28
P	KR3	27%	exposed	OF	R	9	27
P	KR3	27%	exposed	OF	R	9	29
P	KR3	27%	exposed	OF	R	9	27
P	KR3	27%	exposed	OF	R	9	27
P	KR3	27%	exposed	OF	R	9	29
P	KR3	27%	exposed	OF	R	9	28
Q	KR3	25%	exposed	F	R	6	17

Q	KR3	25%	exposed	FJ	L	5	15
Q	KR3	25%	exposed	M	L	6	16
Q	KR3	25%	exposed	M	R	6	16
Q	KR3	25%	exposed	M	R	8	24
Q	KR3	25%	exposed	MJ	L	5	16
Q	KR3	25%	exposed	MJ	R	5	14
Q	KR3	25%	exposed	OF	L	8	26
Q	KR3	25%	exposed	OF	L	9	25
R	KR4 East	24%	sheltered	F	R	10	31
R	KR4 East	24%	sheltered	M	L	8	22
R	KR4 East	24%	sheltered	M	L	9	28
R	KR4 East	24%	sheltered	M	L	9	27
R	KR4 East	24%	sheltered	M	L	9	30
R	KR4 East	24%	sheltered	M	L	10	28
R	KR4 East	24%	sheltered	M	R	8	25
R	KR4 East	24%	sheltered	M	R	9	27
R	KR4 East	24%	sheltered	M	R	9	29
R	KR4 East	24%	sheltered	M	R	10	30
R	KR4 East	24%	sheltered	OF	L	8	26
R	KR4 East	24%	sheltered	OF	L	10	30
R	KR4 East	24%	sheltered	OF	L	10	30
R	KR4 East	24%	sheltered	OF	L	10	32
R	KR4 East	24%	sheltered	OF	L	11	32
R	KR4 East	24%	sheltered	OF	R	10	32

Appendix IV

Table 3: Raw data pf other prawns collected, from 1 Jan 2004 to 18 Mar 2004

Sampling Fieldtrip	Sample site	Sampling method	Location	Salinity (%)	Overstorey cover	Prawn species	Quantity
5	I4	quadrat	Buloh east channel	26%	sheltered	*Athanas polymorphus*	1
9	L4	quadrat	KR4 West	24%	sheltered	*Athanas polymorphus*	1
10	M1	quadrat	KR4 West	25%	sheltered	*Athanas polymorphus*	1
11	N2	quadrat	KR4 East	23%	expose	*Athanas polymorphus*	1
11	O4	quadrat	KR4 East	24%	sheltered	*Athanas polymorphus*	1
13	Q	quadrat	KR3	25%	expose	*Athanas polymorphus*	3
14	R	quadrat	KR4 East	24%	sheltered	*Athanas polymorphus*	2
3	E	point sampling	Buloh east channel	21%	sheltered	*Caridina propinqua*	3
4	E	point sampling	Buloh east channel	21%	sheltered	*Caridina propinqua*	6
3	D	point sampling	KR4 stream junction	NA	expose	*Leandrites* spp.	7
3	F	point sampling	KR4 West	NA	expose	*Leandrites* spp.	3
3	G	point sampling	Buloh east channel	NA	sheltered	*Macrobrachium equidens*	3
9	L2	quadrat	KR4 West	24%	sheltered	*Metapenaeus ensis*	2
9	L3	quadrat	KR4 West	24%	sheltered	*Metapenaeus ensis*	2
9	L4	quadrat	KR4 West	24%	sheltered	*Metapenaeus ensis*	1
10	M1	quadrat	KR4 West	25%	sheltered	*Metapenaeus ensis*	7
10	M2	quadrat	KR4 West	25%	sheltered	*Metapenaeus ensis*	1
11	N1	quadrat	KR4 East	23%	expose	*Metapenaeus ensis*	3
11	N2	quadrat	KR4 East	23%	expose	*Metapenaeus ensis*	2
11	O1	quadrat	KR4 East	24%	sheltered	*Metapenaeus ensis*	3
11	O3	quadrat	KR4 East	24%	sheltered	*Metapenaeus ensis*	1
1	A	point sampling	KR4 East	NA	expose	Penaeid prawns	12
1	B	point sampling	Buloh east channel	NA	expose	Penaeid prawns	7
3	D	point sampling	KR4 stream junction	NA	expose	Penaeid prawns	1
4	H	point sampling	KR4 West	NA	sheltered	Penaeid prawns	4
14	R	quadrat	KR4 East	24%	sheltered	*Potamalpheops johnsoni*	1
2	C	point sampling	Buloh east channel	NA	sheltered	*Potamalpheops johsoni*	1
2	C	point sampling	Buloh east channel	NA	sheltered	*Potamalpheops tigger*	1
5	I4	quadrat	Buloh east channel	26%	sheltered	*Potamalpheops tigger*	2
6	K	point sampling	KR4 West	NA	sheltered	*Potamalpheops tigger*	3
9	L3	quadrat	KR4 West	24%	sheltered	*Potamalpheops tigger*	1
9	L4	quadrat	KR4 West	24%	sheltered	*Potamalpheops tigger*	4
11	O3	quadrat	KR4 East	24%	sheltered	*Potamalpheops tigger*	1
11	O4	quadrat	KR4 East	24%	sheltered	*Potamalpheops tigger*	2
14	R	quadrat	KR4 East	24%	sheltered	*Potamalpheops tigger*	10