

## Distribution of *Onchidium damelii* Semper (Gastropoda, Onchidiidae)<sup>1</sup>

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**ABSTRACT:** The pulmonate gastropod *Onchidium damelii* Semper has a wide-spread tropical Indo-Pacific intertidal distribution. The present study examines some environmental factors in relation to the local distribution and density of the species in a tropical mangrove region.

Tidal regime, floral zonation, substrate particle size and organic content, and temperature relationships were investigated.

*O. damelii* shows habitat preference rather than a zonal (tidal pattern) distribution within the mangroves; population density is associated with substrate particle size and organic content. Considerable differences in size of individuals were noted between populations, probably related to available organic matter and feeding time.

Animal temperatures were correlated with substrate temperatures and do not appear to influence distribution patterns.

THE SHELL-LESS GASTROPOD FAMILY ONCHIDIIDAE is widely distributed, particularly in the tropical and sub-tropical Indo-Pacific (Hoffman 1929; Allan and Bell 1947; Dakin et al. 1952), predominantly inhabiting the intertidal zone of rocky, mangrove, and estuarine shores.

The ecology of the family has been largely neglected. Arey and Crozier (1921) included observations of habitat in their description of the behavior of *Onchidium floridanum* (Dall), and Fretter (1943) gave some ecological information in her study of the functional morphology of *Onchidella celtica* Forbes and Hanley. Various aspects of the ecology of *Onchidium verruculatum*<sup>3</sup> Cuvier were discussed by McFarlane (1979).

The only statement traced concerning a mangrove onchiid is Dakin's paper (1947) describing very briefly the habitat of *Onchidium damelii* Semper on the New South Wales coast.

The present comments are the result of a study of the distribution of *Onchidium damelii* in a tropical mangrove locality at Magnetic Island (Queensland, Australia).

In previous studies of mangrove fauna from Magnetic Island, Macnae (1966) listed *Onchidium damelii* only and Shanco (1975) listed two *Onchidium* spp (not identified). Bretnall's (1919) key, based on male reproductive structures, was used to establish the identity of the study species as *O. damelii*, in the present observations.

### LOCALITY

The mangrove area studied is located at Cockle Bay on the west coast of Magnetic Island (lat 19°11'S, long 146°50'E) approximately 8 km offshore from Townsville, Australia. This mangrove stand has been described as typical of the northeastern Australian mangrove flora (Macnae 1966; Spenceley 1982a).

The mean annual air temperature at Townsville is 24.4°C, ranging from a mean maximum of 28.2°C to a mean minimum of 20.6°C. Highest temperatures occur in January and lowest in July (Oliver 1978; Spenceley 1982a). Variations in sea water temperatures parallel the trends of the air temperature fluctuations, with maximum temperatures recorded in January (mean 31.2°C) and minimum records from July (mean 21.8°C) (Kenny 1974).

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<sup>3</sup> Nomenclature changed from *O. personii*; McFarlane, pers. comm.

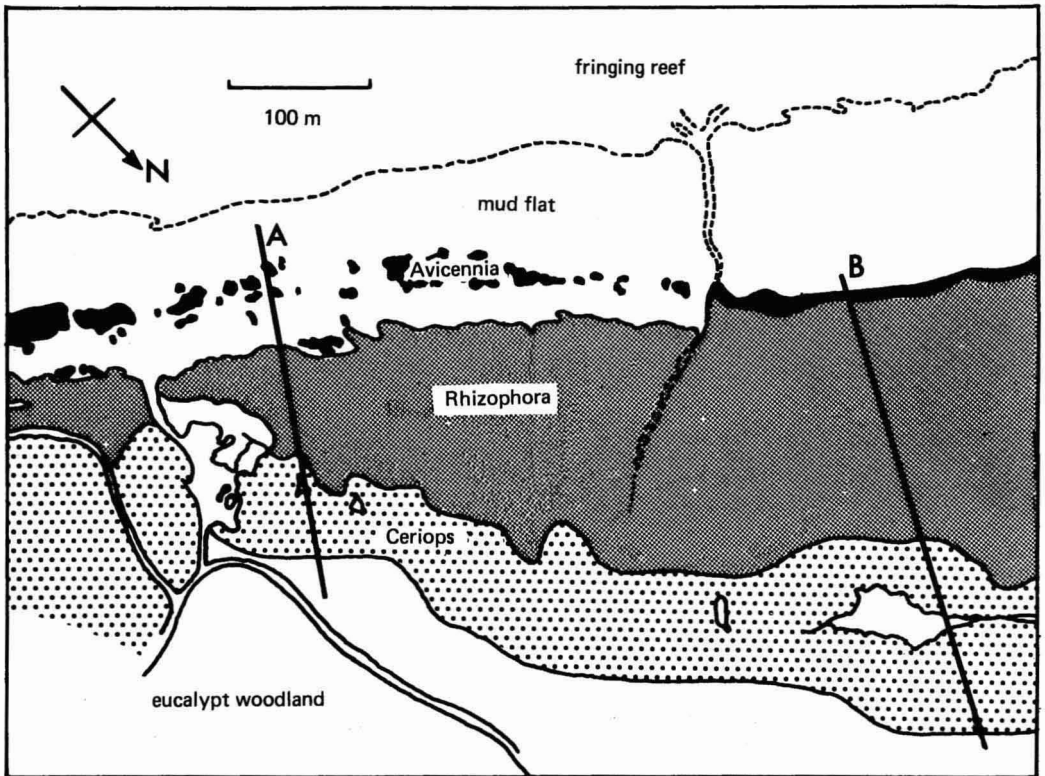


FIGURE 1. Map of the Cockle Bay study area showing transects A and B and the major vegetation zones.

The mean spring and neap tidal ranges for Townsville Harbour are 2.27 m and 0.59 m respectively (Queensland Department of Harbours and Marine 1981). Easton (1970) described the tidal pattern for the area as semi-diurnal with significant diurnal inequality.

The average annual precipitation for the area is 1163 mm (years 1871 to 1970). The Townsville rainfall pattern is highly seasonal, with 90% of the rain falling between November and April, and is characterized by low reliability (Oliver 1978).

#### METHODS

The study site was visited on 33 occasions.

Two transects, approximately perpendicular to the shore line were laid through the mangroves from extreme high water of spring

tides to mean low water of neap tides (Figure 1). The two transects were approximately 0.5 km apart. Transect A included a non-mangrove sand bar, but transect B avoided this habitat intrusion. Profiles of each transect were determined relative to an arbitrary datum and known tidal heights using a dumpy level and staff.

The number of tidal inundations per annum was calculated for several levels using the 1981 tidal predictions (Queensland Department of Harbours and Marine 1981) (Figures 2 and 3).

The distribution of the onchiids was determined along a 2 m wide strip for each transect in May. The number of *O. damelii* in each 2 m length of the transect was recorded (i.e. N per 4 m<sup>2</sup>). Repeat counts were made on successive days, for both transects, during the two hours prior to low tide, when low tide was in

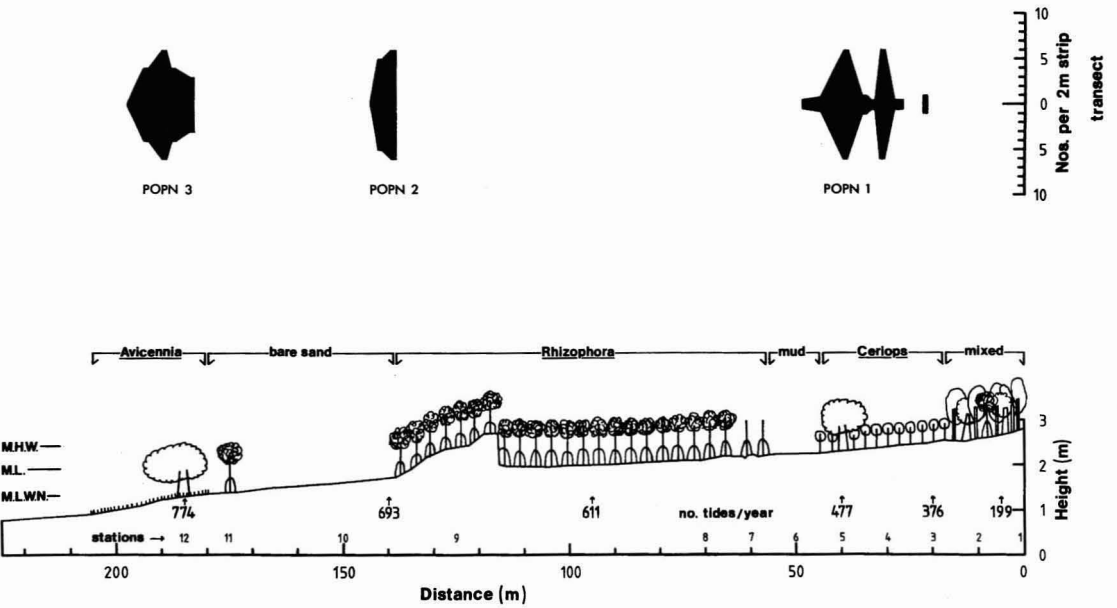


FIGURE 2. Diagrammatic representation of transect A, showing shore profile, number of tidal inundations per annum, sediment sampling stations, mangrove zones, and distribution of *O. damelii* populations.

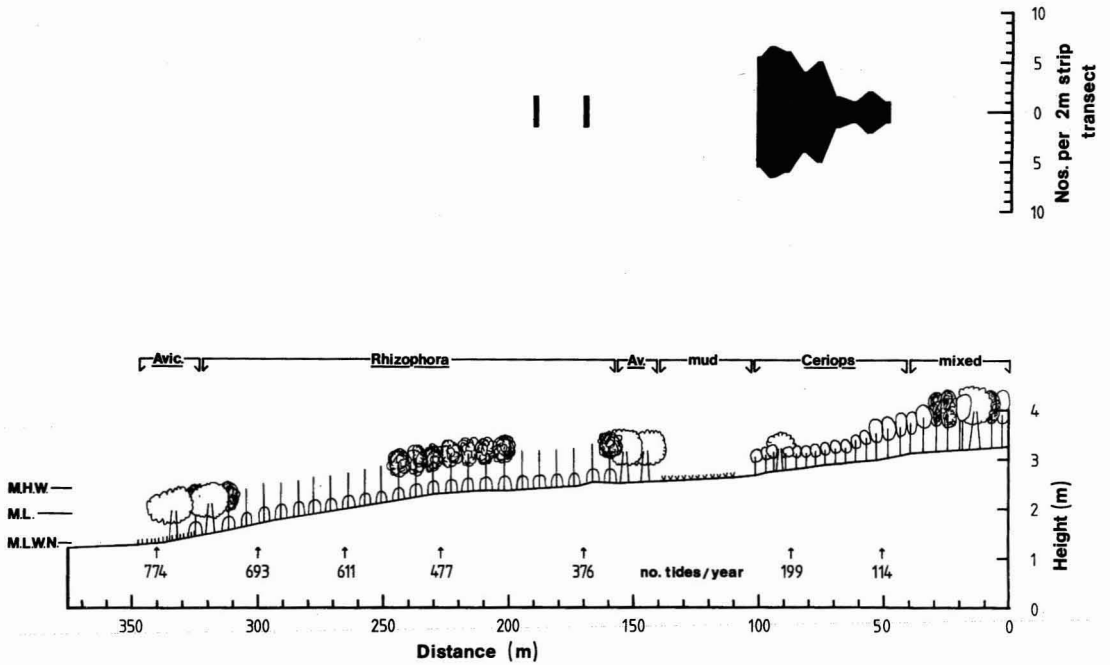


FIGURE 3. Diagrammatic representation of transect B, showing shore profile, number of tidal inundations per annum, mangrove zones, and distribution of *O. damelii* populations.

the middle of the day (coinciding with the observed period of greatest onchiid activity). Other counts, for comparison, were made both before and after low tide on occasions when low tide occurred earlier or later in the day.

Size distribution was based on total body length. Laboratory measurements of wet weight, dry weight, and displacement volume were carried out. Volume estimations were highly correlated with both wet and dry weights ( $r = 0.99$ ). There was a high correlation ( $r = 0.93$ ) between volume and total length and field measurements of length were considered to be a legitimate measure of size. Measurements were made with vernier calipers, to the nearest millimetre. Specimens from each of populations "one" and "two" (transect A) (Figure 2) were measured after allowing the animals to relax on a sheet of wetted perspex.

In the field, lengths of all animals noted in a 100 m<sup>2</sup> area were measured in situ during April, May, July, and September.

Population density counts were made at three 100 m<sup>2</sup> sites during May. One site was situated in the seaward *Avicennia eucalyptifolia* stand; and two areas 50 m apart, including bare mud and vegetation, in the *Ceriops tagal* zone were used (Figure 1). Preliminary observations had suggested that these were areas with high population densities of *O. damelii*.

Density estimates were made during two hours prior to a "middle of the day" low tide. Using random numbers as coordinates, 35 × 1 m quadrats were chosen for counting. The number of individuals in each quadrat was recorded. Trials suggested that a minimum sample size of 20 to 25 quadrats was required to produce statistically acceptable mean counts. Subjective assessments of onchiid densities were also made on each visit to the study site at various times of the diurnal and tidal cycle.

Sediment samples were collected from 12 stations along transect A (Figure 2). The top 5 mm of substrate was lifted from an area of 25 cm<sup>2</sup> and each sample returned to the laboratory in a sealed plastic bag. The samples

were wet-seived through a set of Endecott laboratory sieves (Wentworth scale; 2 mm, 1 mm, 500 μ, 250 μ, 125 μ, 63 μ). Each sediment fraction was dried at 65°C for 24 hours and weighed. The sediment fraction weights were expressed as a percentage of the total sediment weight and converted to *psi* values, using tables provided in Folk (1961). For each station the mean particle size and standard deviation (as a sorting coefficient) were determined using the cumulative percentage frequency method (Folk 1961).

The sediment fractions were incinerated for two hours in a muffle furnace at 600°C and reweighed. The amount of organic matter lost was calculated and expressed as a percentage of the weight of the sediment fraction. The estimates of organic content for the various sediment size fractions must be considered as approximations only, because of the incineration of the calcium carbonate content with each sample in processing. In larger particle size samples (e.g. 1 mm, 2 mm) the organic content included macroscopic items such as leaves and twigs.

Air, substrate surface, and standing-water temperatures were recorded in both sun and shade areas in July. Although July is in the winter period, it is a time of high levels of solar radiation. Body temperatures of several onchiids were taken at the same time. In one series, readings were made hourly, for up to eight hours, spanning a daytime low tide. A total of 86 observations relating body and environmental temperatures were made during these recording sequences.

A telethermometer (Yellow Spring Instrument Co., 46 TUC, series 400) with an air probe, a "needle" probe and a "small surface" probe were used in recording temperatures. The probes were calibrated using a mercury-in-glass thermometer in the laboratory. For recording animal temperatures the "small surface" probe was inserted through the pneumostome aperture, which then closed around the probe; it can be assumed that the recorded temperature was characteristic of the internal temperature regime of the organism. Trials were made using different telethermometer probes, all producing similar results.

## RESULTS

*Mangrove Distribution*

Profiles resulting from the surveys of transects A and B are shown in Figures 2 and 3. The plant zonation pattern (Figure 1) showed a mixed woodland zone (landward fringe) above the highest tides and a high tide *Ceriops tagal* zone which was separated from the mid tidal *Rhizophora stylosa* by a sparsely vegetated mud area. At transect A the *Rhizophora* zone was separated from the seaward *Avicennia eucalyptifolia* zone by a sand bar intrusion, but at transect B these two floral zones were contiguous. The lower seaward area of the *Rhizophora* zone included a large number of moribund plants. The *Avicennia* zone included many *Sonneratia* sp. trees (see also Macnae 1966).

The pattern of distribution of these major mangal zones relative to tidal heights differed at the two surveyed transects. The number of tidal inundations per annum relative to a particular floral zone is considerably greater at transect A than at transect B (Figures 2 and 3).

The only region of the surveyed mangrove area which was inundated at every high tide was the seaward fringe of the *Avicennia* zone, which was below mean sea level. In contrast the *Ceriops* zone may remain exposed by the tide for periods of several days.

*Distribution of Onchidium*

The patterns of distribution of *O. damelii* along the two transects are shown in Figures 2 and 3. The diagrams show the observed numbers of individuals on the substrate surface in the period immediately preceding day-time low tides.

On transect A, three distinct populations were noted. Population "one" (in the *Ceriops* zone) was the largest numerically; population "two", which appeared to be an isolated group, was situated at the seaward edge of the *Rhizophora* zone and was separated from population "three" by a large expanse of sandy mud. Population "three" existed in the *Avicennia* zone and was restricted to areas

covered by the foliage canopy. General observations in areas adjacent to the transect confirmed the existence of these three distinct and separated populations. No *O. damelii* were observed landward from the *Ceriops* zone, in the main part of the *Rhizophora* zone, or on the sand intrusion between the *Rhizophora* and *Avicennia* zones (Figure 2).

Along transect B, onchiids were observed commonly within the *Ceriops* zone and a small number were recorded in the moribund tree area of the *Rhizophora* zone (Figure 3).

The *Onchidium* population in the *Ceriops* zone on transect B corresponded in position, relative to the mangrove zones, with population "one" on transect A. The tidal heights associated with these populations differed, the transect B population being distributed in areas between 2.65 m and 3 m above datum, whereas population "one" (transect A) ranged from 2.3 m to 2.4 m above datum. In terms of number of tidal inundations per annum, the transect B population was covered by sea water 100 to 200 times and the transect A population "one" on 380 to 500 occasions (Figures 2 and 3).

*Size Distribution*

The body length measurements recorded from populations "one" and "three" (transect A) from April to September are shown in Table 1. Animals from population "one" ranged in length from 16 to 68 mm and those from population "three" from 2 to 47 mm. The differences between the size ranges of the two populations were accentuated by the differences between the mean length values. In the April–May period the mean lengths for populations "one" and "three" were 53 and 27 mm respectively. From the July and September samples the mean length of population "one" was 48 and 52 mm respectively while at the same times the mean value for population "three" was 16 mm (Table 1).

The mean length value for population "one" did not change markedly from April (53 mm) to September (48 mm) although some smaller individuals were recorded in the July and September observations. In contrast, the

TABLE 1  
SIZE DISTRIBUTIONS (LENGTHS IN mm) FOR POPULATIONS "ONE" AND "THREE" ON TRANSECT A,  
ON FOUR OCCASIONS

DATE	11.4.81	29.5.81	17.7.81	13.9.81
POPULATION "ONE"				
n	68	75	65	67
range	38-66	40-65	16-68	23-63
mean	53.1	53.3	51.7	47.5
st.d.	4.6	4.9	8.0	8.8
POPULATION "THREE"				
n	100	74	91	67
range	16-38	9-47	2-46	7-35
mean	26.4	27.9	16.8	16.1
st.d.	5.7	7.7	8.4	6.6

TABLE 2  
MEAN GRAIN SIZES AND SORTING CHARACTERISTICS OF AND ORGANIC CONTENT OF THE SEDIMENT SAMPLES  
FROM TRANSECT A

STATION	GRAPHIC MEAN $M_z$		WENTWORTH SIZE CLASSIFICATION OF $M_z$	INCLUSIVE GRAPHIC STANDARD DEVIATION $\sigma_1$	SORTING CLASSIFICATION	% ORGANIC CONTENT
	$\phi$	mm				
1	-0.17	1.13	Very coarse sand	1.30	Poorly sorted	2.42
2	-0.12	1.08	Very coarse sand	1.32	Poorly sorted	2.61
3	0.8	0.57	Coarse sand	1.89	Poorly sorted	6.00
4	2.93	0.13	Fine sand	2.07	Very poorly sorted	29.90
5	1.13	0.47	Medium sand	1.85	Poorly sorted	2.80
6	3.2	0.11	Very fine sand	2.12	Very poorly sorted	25.26
7	0.53	0.69	Coarse sand	1.92	Poorly sorted	8.82
8	1.4	0.38	Medium sand	2.05	Very poorly sorted	10.66
9	-0.63	1.55	Very coarse sand	0.42	Well sorted	0.41
10	0.93	0.52	Coarse sand	1.88	Poorly sorted	2.81
11	0.63	0.64	Coarse sand	1.90	Poorly sorted	2.10
12	0.57	0.67	Coarse sand	1.92	Poorly sorted	2.31

records for population "three" showed a distinct shift towards smaller individuals, from a mean value of 27 mm in the April-May period to approximately 16 mm in July and September.

#### Population Density

The population density estimates from two areas within the population "one" habitat in the *Cerriops* zone resulted in mean counts of 1.6  $0.4 \text{ m}^{-2}$  and 1.2  $0.5 \text{ m}^{-2}$ . Counts from the population "three" area under the seaward *Avicennia* stand showed a population density of 0.9  $0.4 \text{ m}^{-2}$ .

General observations on the density distribution of onchiids within these different populations indicated that *O. damelii* may be radially distributed around vegetation features such as *Cerriops* buttresses and *Avicennia* pneumatophores.

#### Sediment Analyses

The results of the sediment analyses from the transect A sampling are presented in Table 2. The mean recorded particle size of the sediments decreased from a value of 1.13 mm at station 1 (above high water) to 0.11 mm at station 6 in the sparsely vegetated mud area

near mean high water. The general trend in the lower part of the mangrove area was for mean particle size to increase with progression down the beach to a value of 0.67 mm at station 12. Exceptions were the sand bar intrusion (mean particle size 1.55 mm at station 9) and the coarse sand value (0.69 mm), calculated from the results of sampling at station 7 near the upper level of the *Rhizophora* zone.

The particle size analyses showed that the sediments at all sampling stations were poorly sorted, with the exception of station 9, in the sand bar area (Table 2).

The percentage of organic content for each station sample on transect A is listed in Table 2. The highest organic content levels were recorded at stations 4 and 6, with values between 25 and 30% of the sediment sample by weight. These two stations showed the lowest mean particle sizes and were two of the very poorly sorted samples (Table 2).

The lowest values for percentage organic content were calculated for stations at the top (corresponding to levels above mean high water, stations 1 and 2) and bottom (stations 10 to 12, below mean tide level) of the transect. These stations, with low levels of organic content in the substrate, were also the sampling sites that showed the larger mean particle sizes.

The station 9 (transect A) samples showed an extremely low organic content. This sampling site was part of the sand bar intrusion with a large mean particle size and a high level of sorting.

A detailed analysis of the physical and chemical composition of sediments from samples on transect B is given by Spenceley (1982b).

### Temperature Relationships

The results from the field recordings of environmental and onchiid temperatures are shown in Figures 4 and 5.

The body temperatures of the onchiids, in general, followed the temperature trend of the substrate. For both populations tested there was a high correlation between body temperature and substrate temperature ( $r = 0.94$ , population "one";  $r = 0.79$ , population

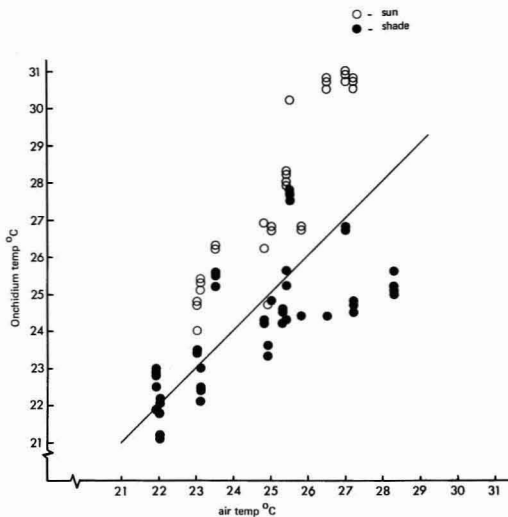


FIGURE 4. Relationship between *O. damelii* temperature and air temperature.

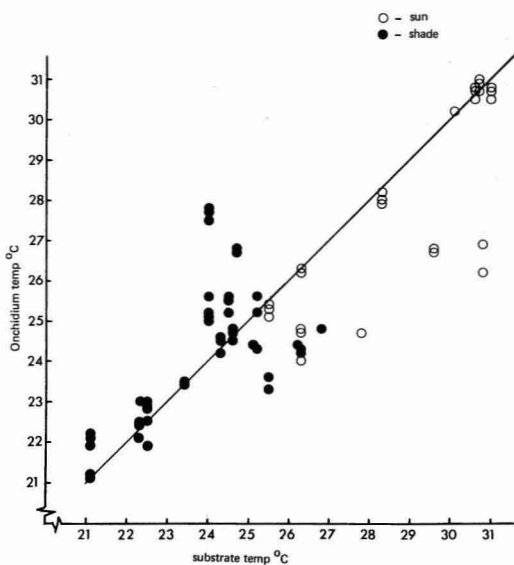


FIGURE 5. Relationship between *O. damelii* temperature and substrate temperature.

"three"). The correlation between animal temperature and air temperature was not as well defined as for the substrate relationship ( $r = 0.66$  and  $r = 0.54$  for the two populations, respectively).

At the time of the July readings, for population "one", the air temperature ranged from

21.9°C (shade) to 32.0°C (sun). For population "three" the air temperature varied from 23.0°C to 26.5°C. The substrate temperature ranged from 23.4°C (shade) to 30.8°C (sun). The maximum body temperature recorded was 30.8°C.

Animals exposed to the sun had higher body temperatures than those in shaded areas. The relationship between air temperature and animal temperature (Figure 4) was such that recordings from individuals in the sun showed temperatures above the ambient air temperature for more than 95% of the sampled populations (both "one" and "three"); while shaded individuals tested showed only 36% registering temperatures above the equilibrium level.

The substrate-body temperature relationship (Figure 5) showed that at substrate temperatures of 25°C and below (i.e. in shade), 70% of the onchidia sampled had body temperatures above the associated substrate recording, but at higher temperatures, in sunny conditions (substrate temperatures 26 to 31°C), more than 75% of the sampled animals had body temperatures lower than the substrate readings.

Following a series of comparative readings on individual animals over several hours, the animal body temperatures reached a peak above the environmental temperature and then declined to temperatures similar to, or below those of the substrate.

#### DISCUSSION

The sequence of mangal vegetation zones observed was not as complex as that recorded by Macnae (1966) for this area. Factors contributing to this may include natural succession or modification of the pattern resulting from the 1971 cyclone.

The differences in substrate level relative to tidal heights at the two transects and the associated differences in the number of tidal inundations per annum probably contribute to the variations in floral distribution at the two sites; and differences in the landward extent of the *Ceriops* zone have been attributed to geomorphic influences (Spenceley 1982a).

On transect A, the significant influence on

mangal distribution (and secondary distribution of other organisms) is the area of coarse sediment being reworked and transported to form a sand spit in front of the mangroves.

The distribution of the onchiids on the two transects does not show a direct correlation with the number of tidal inundations or tidal height and appears to be more dependent on the vegetation zones. This may reflect an indirect tidal effect. In particular the pattern of distribution of the upper populations of *O. damelii* concentrated in the *Ceriops* area appears to be directly influenced by the vegetation zones. This may be related to the production of vegetation detritus as a source of substrate organic matter.

Reasons for the significant difference in sizes of individuals between populations "one" and "three" (transect A) are difficult to assess. Population "three" is exposed at low tide for shorter periods than population "one", and therefore these organisms are active and feeding for a shorter time. During neap tide periods population "three" may remain submerged for a number of days, restricting the possible feeding time. The percentage organic content of sediment samples from the population "one" area is much higher than that from the population "three" area, suggesting a greater relative nutritional value for the sediments in area "one". These factors may account in part for the size discrepancy.

A possible explanation for the shift of mean length values in the July and September sampling could be recruitment of juveniles into the population at this period of the year.

The pattern of particle size distribution in the sediment samples from transect A and the poorly sorted nature of these samples could be due to the sediments, derivation from two sources. The landward zones are subjected to surface drainage from the hills behind the mangroves, with wet season heavy rains carrying coarse grains into the *Ceriops* zone. These are combined with the fine terrigenous sediments deposited by the tides. The coarse material forming the sand bar, in combination with the tidal-deposited sediment, produces the larger mean particle sizes recorded at the lower end of the transect. These variations in sediment characteristics perhaps influence



the vegetation pattern, and thus the onchiid distribution. Substrate samples with small particle size and high organic content were associated with the high density, large size population "one".

*Onchidella celtica* and *Onchidium* sp. have also been shown to feed on diatoms and detritus (Graham 1955), which would be associated with the smaller sediment sizes (<125  $\mu$ m).

The areas of maximum density of onchiids on transect B coincided with the smaller mean particle size samples recorded by Spenceley (1982b).

Particle size and associated organic content of the substrate appear to be the most important factors influencing onchiid distribution, with the distribution of mangroves (also influenced by substrate particle size) as a secondary factor.

The high percentage of individuals showing body temperatures above the ambient air temperature suggests that direct radiation and conduction from the substrate are the means of heat absorption by these onchidiids, and the high water content within the body retains this heat energy.

As the body color and surface sculpture of *O. damelii* closely resemble those of the sediment surface, it may be expected that the animals and the substrate would have similar radiation balance totals. The general trend of agreement between recorded environmental and animal temperatures supports this proposition.

At higher ambient temperatures (in sun), a greater number of onchidia exhibit body temperatures lower than the substrate under cooler conditions, suggesting the possibility of evaporative cooling. Kenny (1958) showed that for an intertidal rock dwelling chiton, *Clavarizona hirtosa*, evaporative physical effects could lower the body temperature relative to that of the substrate by more than 5C in dead animals. The amount of moisture on the body surface of *O. damelii* appears to be similar to that on the sediment surface and effects of evaporative cooling from the animal and substrate would be expected to be similar.

Behavioral mechanisms are probably important in relation to temperature balance.

During periods of extreme high temperature, the majority of observed onchidia were feeding in shaded areas.

Various intertidal invertebrate temperature tolerance studies have stressed the inter-relationship between temperature and desiccation. In this *Onchidium*-mangrove situation, it is unlikely that temperature or desiccation would be a limiting factor in distribution of *Onchidium damelii*.

#### ACKNOWLEDGMENT

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