

## The Impacts of Fiddler Crabs on Sediments of Mangrove Shores

ALEX S. W. RETRAUBUN  
UNIVERSITAS PATTIMURA

MIKE DAWSON AND STEWART M. EVANS  
UNIVERSITY OF NEWCASTLE UPON TYNE

### 1. Introduction

The impact of burrowing organisms on the sediments they inhabit is likely to be an important and fruitful area of research (e.g., Meadows & Meadows 1991). However, it is relatively underdeveloped. Crabs are particularly important burrowers in mangrove sediments, but there is a paucity of information on, for example, their burrow systems, the amount of sediment that is turned over (bioturbation) as a result of burrowing and other activities, and the effects of their activities on other organisms that inhabit the same sediment. The object of this study is to provide information of this kind for two inhabitants of mangrove shores in Maluku, the fiddler crabs *Uca lactea* and *Uca vocans*.

*U. lactea* and *U. vocans* commonly occur on the same shores. Although their distributions overlap, *U. lactea* tends to be dominant in the drier sediments near high water, while *U. vocans* dominates wetter areas lower down the shore (Icely & Jones 1978). Both species emerge from their burrows during periods of low water in daylight only. At such times, they perform two activities that rework sediment. First, they construct new burrows or repair existing ones, thereby bringing “deep” sediment to the surface. Second, they filter microorganisms from surface sediment and ingest them as food. Diatoms and bacteria are major foods for several—probably most—fiddler crabs (e.g., Robertson et al. 1981, Dye & Lasiak 1987). The minor chelae are used to scoop sediment into the buccal cavity, where food is separated from sediment by the scouring action of the setae on the first and second maxillipeds (Miller 1961). The buccal cavity is flushed with water, and the lighter organic food particles

are washed into the gut. Heavier sand grains are left and redeposited on to the surface as characteristic “foodballs.”

Three studies were undertaken in the present investigation:

(a) Measurements were made of the density of crabs and the dimensions of their burrows. Estimates were then made of the extent to which burrows increase the surface area of the sediment. This area is important because it is where sediment interphases with air during low tide and water during high tide, and where a range of chemical exchanges takes place.

(b) Measurements were made of the amounts of sediment that were turned over as a result of the feeding activities of crabs.

(c) A study was made of the extent to which crabs control numbers of diatoms (food) in the sediment. Cages were constructed whereby crabs could be either confined to certain areas or prevented from foraging on them.

## **2. Study area and methods**

Field observations were carried out on tidal flats at Passo, in inner Ambon Bay. Passo contains 36% of the total mangrove area within the Bay. The study site was an area of tidal flat approximately 50m x 50m. It was at about midtide level, where *U. lactea* and *U. vocans* overlapped in their distributions. The study period was between July 1993 and January 1994.

### **a. Densities of crabs and their burrows**

The density of crabs was determined by digging out sediment within a 0.5m x 0.5m frame to a depth of 20–25cm in 50 quadrats. The sediment was sieved through a 2mm sieve. Crabs retained in it were identified and sexed. The structure of the burrows was investigated by “prizing” them open with a spade. It was found that, if the blade of the spade was pushed into the substrate about 10cm from the burrow and then pressure applied as if to raise the sediment, the sheer plane often dissected the burrow. It was possible to “lift” the exposed burrow and measure the length and diameter of the shaft. Each burrow occupant was captured and sexed.

### **b. Feeding activities**

An Optolyte telescope was used to observe crabs that were foraging on the sediment. Records were kept of the rate at which sediment was trans-

ferred by the chelipeds from the substrate to the mouth. This was done for medium-sized crabs only (estimated carapace length 7–10mm). In addition, records were kept of the rate at which feeding crabs produced foodballs. In order to estimate the numbers of crabs that were foraging during a tidal cycle, records were kept of the numbers on the surface within marked 1m x 1m squares. This was done at one-minute intervals throughout 10 complete periods of low water.

### c. Cage experiments

Eight cages were constructed that could be used either to confine crabs to particular areas of sediment or to deny them access to those areas. Each cage measured 1.5m x 1.5m, and was made with a strong wooden frame and “waring” (minnow net). The height was 70cm, with 20cm (including net) below the sediment surface. Each enclosure was also screened with 25cm-wide wooden planks into the sediment so that crabs or other organisms of similar sizes could not burrow into or out of it. All crabs were removed after digging them out of the substrate. One week later, groups of 21 *U. lactea* were introduced into three cages and groups of 21 *U. vocans* into three other cages. In both species, the ratio between males and females was 11:10. Two cages were left empty (i.e., there were no crabs in them).

Sediment samples were taken for chlorophyll analysis (as indirect estimations of diatom abundance) from each of the cages. This was done when crabs were first introduced into the cages (0 days), and then at 7 and 14 days later. Chlorophyll analysis was carried out at the laboratory of the National Oceanological Institute (LON) at Ambon. Subsamples of 2cm<sup>3</sup> sediment were ground for one minute inside a dark room, centrifuged for 10 minutes, and the total chlorophyll determined by measuring optical densities in a Shimadzu Spectrophotometer UV-120-02.

## 3. Results

### a. Densities of crabs and their burrows

Both *U. lactea* and *U. vocans* were abundant in the study area, although *U. lactea* was relatively more common (Table 1). The sex ratio was approximately equal in *U. lactea*, but heavily female-biased in *U. vocans*.

The burrow systems of both *U. lactea* and *U. vocans* were curved tubes, most of them less than 15cm long. In general, *U. lactea* burrows were smaller than those of *U. vocans*, particularly those of male *U. lac-*

*tea* (Table 1). The presence of *Uca* burrows increased the surface area of the sediment by approximately 13–14% in both species (Table 1).

**Table 1. Estimated internal surface areas of burrows and effective increases in surface area of sediment.**

	<i>U. lactea</i>		<i>U. vocans</i>	
	MALE	FEMALE	MALE	FEMALE
Number burrows measured	20	20	20	20
Length (cm)	9.7±0.3	14.2±1.2	14.4±1.3	14.8±0.6
Internal surface area (cm <sup>2</sup> )	14.2±3.1	48.3±0.9	51.9±4.5	56.0±6.0
Density of burrows on shore (n/m <sup>2</sup> )	25.2	22.5	6.8	17.6
Increase in surface area (%)	14.4		13.4	
Total increase in surface area (%) for both species			27.8	

**b. Feeding behavior**

The feeding process was similar in both *U. lactea* and *U. vocans*. Surface sediment was scooped up with the single feeding cheliped in males, but by both chelipeds in females. Foodballs were rejected and left as pellets on the surface sand. The feeding rate (i.e., number of times chelipeds reached the mouth) was faster in females than in males in both species (P<0.001; t Test) (Table 2). The faster female rate could be attributed to the use of both chelipeds. The single male cheliped actually worked faster than either of the female chelipeds alone. The rate of foodball production in both *U. lactea* and *U. vocans* was also significantly faster in females than in males (P<0.001; t Test).

The mean numbers of crabs foraging at the surface varied throughout the tidal cycle. Males undoubtedly spent longer there than females, and were recorded relatively more often (Table 3). Based on the mean numbers recorded foraging, *U. lactea* turned over 8.25cm<sup>3</sup> of sediment per hour per m<sup>2</sup> and *U. vocans* about 1.49cm<sup>3</sup> per hour per m<sup>2</sup>.

**Table 2. Feeding rates and foodball production.**

FEEDING RATE		FOODBALL PRODUCTION	
Number crabs observed	scoops/min	Number crabs observed	balls/min

<i>U. lactea</i>				
Male	72	66.8±3.6	8	4.8±0.3
Female	44	105.8±5.8	9	6.7±0.7
<i>U. vocans</i>				
Male	56	66.8±4.3	8	6.5±0.9
Female	38	91.7±7.3	9	10.1±1.5

**Table 3. Estimated turnover of sediment expressed as volume moved per hour and as equivalent to a layer (mm deep). Calculations were based on the assumption that all crabs were medium-sized ones.**

	<i>U. lactea</i>	<i>U. vocans</i>
Diameter of foodballs (cm)	0.19±0.01	0.21±0.02
Volume of foodballs (cm <sup>3</sup> )	0.0042	0.0056
Mean density of crabs at surface/m <sup>2</sup> (i.e., feeding)		
Males	5.5	5.0
Females	1.0	0.5
Rate of football production (n/min)		
Males	4.8	6.5
Females	6.7	10.1
Sediment turnover (cm <sup>3</sup> /m <sup>2</sup> /h)		
Males	6.58	10.81
Females	1.67	1.68
Total for both sexes	8.25	12.49

### c. Cage experiments

Numbers of diatoms in the surface sediment were evidently controlled by the crabs. There was a substantial initial increase in the chlorophyll content of the sediment during the first week (days 0–7). This was followed by decreases in amounts in the experimental and control cages. Nevertheless, in each of the six situations (i.e., three separate chlorophyll measurements for two species) the levels of chlorophyll (and therefore abundances of diatoms) were lower in cages with crabs than those in the controls without crabs at the end of the second week (i.e., when the final measurement was made) (Table 4). Considering both species of crabs together, the impact is significant in the case of both chlorophyll a and chlorophyll c ( $P=0.016$  in both cases; Sign Test).

**Table 4. Chlorophyll content (mg/m<sup>3</sup>) in empty cages and in cages containing *U. lactea* and *U. vocans* 0, 7, and 14 days after the introduction of crabs.**

	DAYS	EMPTY CAGES	CAGES CONTAINING:	
			<i>U. lactea</i>	<i>U. vocans</i>
Chlorophyll a	0	6.1	3.5	3.9
	7	17.1	9.4	15.7
	14	15.6	3.1	6.7
Chlorophyll b	0	0.8	0.4	0.6
	7	2.4	1.0	3.5
	14	0.9	0.6	0.6
Chlorophyll c	0	4.1	2.4	3.1
	7	11.3	7.5	15.7
	14	8.3	2.0	4.7

#### 4. Discussion

Fiddler crabs, *U. lactea* and *U. vocans*, have substantial impacts on the sediments in which they burrow. Three were identified in the present study. First, burrows effectively increase the surface area of the sediment and thereby the interface at which chemical processes occur, such as decomposition, sulphate reduction, and release of inorganic nitrogen (Andersen & Kristensen 1991). Together, burrows of *U. lactea* and *U. vocans* did so by about 28% in the study area. This is less than that described by Katz (1980) in *U. pugnax*. He found that crab burrows at a density of 42/m<sup>2</sup> increased the surface by 59%. Second, *U. lactea* and *U. vocans* rework surface sediment as a result of feeding activities. Third, as a result of removing food from the surface sediment, they control the abundance of diatoms in it. *U. pugnax* also affects the occurrence of the chordgrass *Spartina alterniflora* in New England. Burrowing by the crabs leads to increased production by the plants, whose roots, in turn, stabilize the mud, thus allowing burrowing to occur (Bertness 1985).

#### REFERENCES

- Andersen, F. Q., and E. Kristensen. 1991. Effect of burrowing macrofauna on organic matter decomposition in coastal marine sediment. *Symposium of the Zoological Society of London* 63: 69–88.

- Bertness, M. D. 1985. Fiddler crab regulation of *Spartina alterniflora* production on a New England saltmarsh. *Ecology* 66: 1042–1055.
- Dye, A. H., and T. A. Lasick. 1987. Assimilation efficiencies of fiddler crabs and deposit-feeding gastropods from tropical mangrove sediments. *Comparative Biochemistry and Physiology* 87A: 341–344.
- Icely, J. D., and D. A. Jones. 1978. Factors affecting the distribution of the genus *Uca* (Crustacea: Ocypodidae) on an East African shore. *Estuarine, Coastal and Shelf Science* 6: 315–325.
- Katz, L. C. 1980. The effects of the burrowing of the fiddler crab *Uca pugnax* (Smith). *Estuarine, Coastal and Shelf Science* 4: 233–237.
- Meadows, Peter S., and Azra Meadows, eds. 1991. *The environmental impact of burrowing animals and animal burrows*. Oxford: Clarendon Press for the Zoological Society of London.
- Miller, D. C. 1961. The feeding mechanisms of fiddler crabs, with ecological considerations of feeding adaptations. *Zoologica* 46: 89–100.
- Robertson, J. R., J. A. Fudge, and G. X. Vermeer. 1981. Chemical and live feeding stimulants of the sand fiddler crabs, *Uca pugilator* (Bose). *Journal of Experimental Marine Biology and Ecology* 53: 47–64.

{ PAGE }

CAKALELE, VOL. 9

The lead author for receiving proofs is S. M. EVANS