Observations of Earthworms in Sepilok Forest, Sabah, Malaysia[1]

The activities of tropical earthworms have been described mainly from regions of Africa, India, and Central America (Lavelle 1983). Those studies emphasized the large volume of soil processed by earthworms, the diversity of species, and their biomass. This study focuses on excretory rates and cast production of the megascolecid earthworm, *Pheretima darnleiensis* (Fletcher 1887), in Sepilok Forest, 14.4 km west of Sandakan, Sabah, Malaysia. The range of *P. darnleiensis* (see Sims & Easton 1972 for synonymy) includes the whole Indo-Australasian Archipelago, peninsular Malaysia, the Caroline Islands, and Fiji. The extent to which this distribution has been augmented by accidental human introduction is unknown. A second species of earthworm, *Polypheretima everetti* (Beddard & Fedarb 1895), was also observed. *P. everetti* has been recorded from Palawan, Borneo (up to 2400 m), north and west of Sulawesi and Lombok.

The forest consists of 11,000 ha and contains roughly 450 species of trees, of which 54 belong to the family Dipterocarpaceae (Fox 1973). The study site is located in research plots 6 and 7 (Fox 1973) on a lowland alluvial flat in Sepilok Forest about 30 m above sea level. Under the thick, humic sand is a deep brownish-yellow loamy sand derived from mudstone and sandstone (Acres & Folland 1973). Mean annual rainfall was 3406 mm from 1918 to 1940 (range 2205–4431); maximal precipitation is in December–January and minimal occurs in April–August (Davis 1962).

During the last few days of December, heavy rains washed away all the casts. Rainfall for Sepilok was not unusual (235 mm inches in October and 328 in November 1983) when active casts were abundant throughout the forest. The northeast monsoon had not yet arrived. December saw 1020 mm of rain.

We observed and collected casts between 14 November and 5 December 1983. Excreta were collected using plastic surveyor's tape. Strips of tape were cut into 1020 mm lengths, a 1-cm hole was cut in the center, and the tape was placed over the top of each cast so that the earthworm emerged through the tape hole. Each tape was

TABLE 1. *Density of* P. darnleiensis *casts.*

No. of casts per plot	Area sampled (m^2)	Density/ha	Metric tons/ha of standing casts assuming cast wt = 249 g	Number of plots sampled
63	1010	623	1.5	1[a]
$\bar{x}$ = 41 (range 0–91)	10	41,000	10.2	30[b]
$\bar{x}$ = 25 (range 17–30)	1	250,000	62.3	4[c]
75	111	6756	1.6	1[d]
48	111	4324	1.2	1[d]
$\bar{x}$ = 12	1	120,000	29.9	6[e]
			Total	43

[a] Gentle slope along trail.
[b] At base of trees.
[c] Dug plots near streams.
[d] Sparse vegetation area between trees.
[e] See Table 3.

TABLE 2. *Excretory rate of* P. darnleiensis *measured by cast deposition on plastic flagging.*

No. of casts	g excreted	Deposition time (hr)	Rate (g/24 hr/cast)	Extrapolated rate/earthworm/yr (kg)
12	70.7	15	9.4	3.4
14	44.5	8	9.6	3.5
6	236.9	80	11.9	4.3
6	210.1	80	10.5	3.8
1	42.5	80	12.8	4.7
1	36.0	80	11.1	4.1
4	117.8	80	8.8	3.2
6	210.0	72	11.7	4.3
4	117.8	72	9.8	3.6
2	21.0	24	10.5	3.8
56 casts			$\bar{x}$ = 10.0	3.8

TABLE 3. *Sampling of earthworms from six 1-m² plots 45 cm deep (0.45 m³).*

	Numbers of earthworms				
				P. darnleiensis casts	
Plot number	*P. everetti*	*P. darnleiensis*	*P. sangirensis* and *P. racemosa*	Number	Annual weight[a]
1	2	6	11	12	21.9
2	1	24	7	17	87.6
3	0	7	3	20	25.6
4	3	5	0	18	18.2
5	0	7	3	12	25.6
6	0	10	5	16	36.5

[a] Annual weight is kg/m²/yr, based on an excretion rate of 10 g/day.

numbered and the time it was positioned recorded. From 2 hr to 10 days later, excreta deposited on the tapes were collected and weighed. Some additional observations were conducted by MA in December 1985.

Thirty sample plots were selected for determing cast density; 25 species of trees (N = 30) that had been clearly marked along the Mangrove trail and identified by the Forestry Department were used as plot locations. A plot consisted of a (10-m²) rectangle located 5 m either side of the tree's center and 1 m away from the tree trunk. Seven other plots of varying size were also used to determine cast density. These seven were off the trail and on steeper terrain near fallen trees. Because massive root systems adjacent to trees made digging difficult, soil plots were sampled in spaces between trees. Six holes were dug 1 × 1 × 0.43 m deep. Populations were estimated by hand-sorting. Some casts were weighed before and after heating until dry. Earthworms were preserved in formalin. Specimens were catalogued in the British Museum.

The forest floor of Sepilok Forest was dense with cylindrical casts of *P. darnleiensis,* 623–250,000 casts/ha (Table 1). When an earthworm came to the surface of a cast, it deposited excreta over the surface of the tape. The excreta from an average size *P. darnleiensis* cast weighing 249 g (N = 46; range 47–635 g) is deposited by one earthworm in 23 days, assuming an excretory rate of 10 g/day (Table 2) by one earthworm and assuming no water loss. Because roughly 50 percent of fresh excreta is water (the lower portion of casts are much drier), 30–40 days may be more realistic for the construction time of an average cast. The huge range is explained by some nights of no deposition, rain disintegrating the cast, hot days drying the cast, and some casts being toppled. The annual weight (kg/m²/yr) of casts based on the deposition rate of *P. darnleiensis* (Table 3, median = 25.6 kg) is slightly more than that of nine other tropical earthworms (range 1.3–27.8 kg/m²/yr, median = 21 (Lee 1983).

The greatest number of casts occurred below three tree species: two *Nephelium mutabile* (74 and 78 casts), one *Eusideroxylon zwageri* (81), and one *Anthocephalus chinensis* (91). One *Guanua kingiana* had 35 casts beneath it. The lowest counts (≤12 casts) occurred below: *Shorea smithiana* (0), *G. kingiana* (8), *Dipterocarpus caudiferus* (11), *Shorea leptoclados* (11), and *Shorea xanthophylla* (12). According to P. Watermann (pers. comm.) the leaves of *G. kingiana* are latex rich.

On 1 December 1983, EG censused active casts in seven different areas, each separated by more than 100 m. Of 85 casts noted in regard to activity based on the presence or absence of wet, freshly deposited excreta vs dry tops on casts, 67 percent (57) were active. In December 1985, MA counted active and inactive casts on five 4 m² plots; a total of 662 (69%) were active out of 960 observed. Some casts incorporate both living and dead leaves into the casts. The cast eventually collapses; decomposed vegetation becomes the basis of new earthworm casts. Some casts show clearly three colors representing three distinct horizons: dark brown derived from the thin humic layer, gray-yellow derived from the sandy loam, and an intermediate color that resembles a mix of the two. Some casts become tapered at the base by heavy rain and fall over or become steeply angled. Once fallen, they provide support for other casts.

Our observations of excretory rate and cast weight are the only data on worms in primary tropical rain forest.

The findings suggest that the rate of soil turnover is comparable to or greater than that of worms in tropical savannas, shrub, or pasture (Lee 1983).

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