VERMALCHEMY – ecological economics and taxonomy of vermicomposting

Presentation to Victorian EPA and invited audience at Eden on the Park, Melbourne, 9th March, 2001 by Rob Blakemore.

"*All the fertile areas of this planet have at least once passed through the bodies of earthworms*." - Charles Darwin, 1881.

Introduction:
Earthworms are amongst the most ancient of terrestrial animals, their ancestors emerging in the pre-Cambrian some 600-700 million years ago. Pioneers in the colonization and preparation of the land, they pre-date the invasion by fungi, land plants, insects (400-500m yr), dinosaurs and mammals (200m yr), and hominids (4m yr). They are ubiquitous in all but the driest of regions and the present day world distribution of almost 4000 described species in 18 families have been explained in terms of Wegener's hypothesis of continental drift. Approximately 600 species are known from Australia, although it is estimated that there are actually 5 or 6 times this number. Apart from Victoria's Gippsland Giant, next to nothing is known of the ecology of native species, some of which are ancestral i.e., living fossils.

Because they play a vital role in the formation and maintenance of fertile soils, earthworms are of paramount importance to primary production. Charles Darwin (1837; 1840; 1881) was one of the first scientists to give credence to the conventional wisdom from earlier civilizations about the beneficial effects of earthworms on soils and plant growth, and thus on human survival. Recently there has been a resurgence in interest, driven by environmental and economic concerns, particularly the need to appreciate and utilize their function in sustainable agriculture, horticulture and forestry, and to understand and exploit their potential for restoring damaged soils and for recycling of organic 'wastes'. One steps towards understanding is to reliably identify which species are involved, what are their ecological roles and relationships, and to determine their regional distributions.

<u>Basic biology</u>
Earthworms are promiscuous, polygamous, hermaphrodites but some can reproduce parthenogenetically. Eggs are protected in cocoons from which one or more hatchlings emerge. Food sources are decaying organic matter and/or the microbes that feed on this material. Enzymes and digestive juices are secreted into the pharynx and, rather than jaws, there are muscular gizzards plus grits acting as 'crop stones'. The oesophagus and intestine may have 'calciferous glands', with a variety of functions, and the intestine can have caeca (blind sacs) that incubate symbiotic gut microbes. Excretion is via nephridial tubules and ingested material is voided as 'casts'.

<u>Ecology 101</u>
Worms eat dirt. They are **detritivorous** where they feed on decaying organic matter and **geophageous** where they feed mainly in the soil mineral layers. Earthworms are divided into two broad ecological categories by Buckerfield (1994) - "earthworkers" vs. "composters", the former inhabit topsoil and subsoils, while the latter are drawn mainly from litter species and these specialists decomposers won't generally survive in ordinary field habitats. Earthworms have considerable capacity to change the nature of their environment to suit their survival. Ecological requirements (eg. moisture, temperature, food supply), and rates of reproduction and growth for several vermicomposting species can be found in texts and papers (eg. Lee, 1985; Edwards & Bohlen, 1996). An interesting finding by Miles (1963) was that when *Eisenia fetida* was cultured in sterile soil to which soil fungi and bacteria were added, specimens failed to grow, but when soil protozoa were added, the worms grew to maturity.

Earthworms have many, many predators (eg. grizzly bears, foxes, moles, platypuses, birds, snakes, frogs, fishes, insects, ants, leeches, planarian flatworms, and there is even a cannibalistic earthworm in Africa); and parasites (eg. carnivorous flies, helminths, nematodes, protozoans, bacteria, viruses). Earthworms are the intermediate hosts of certain parasites of higher animals, and have been implicated in the distribution of both pathogenic and beneficial microbes.

Taxonomy in a nutshell

Governed by codes of ICZN (1999), authors give species scientific names to avoid linguistic and regional confusion with vernacular names. Classification is heirarchical and phylogenetic: Species->Genus->Family->Order->Class->Phylum->Kingdom. Genus name always starts with a CAPITAL and may be abbreviated, the species name is lower case, and the authority follows (in braces only if the species has been subsequently transferred to a different genus), eg. *Lumbricus terrestris* Linnaeus, 1758.

Vermicomposting species

Of a worldwide total of almost 4,000 described earthworm species, detailed ecological studies have been made on fewer than 20 of these. (Approx. regional species totals are: UK and Ireland - 45; Japan – 78; France – 97; North America – 160; NZ – 192; Tasmania – 230; India – 350; Australia – 350+).

The three main species used in vermiculture around the world are:

Eisenia fetida (Savigny, 1826) "Tiger Worm" – this, along with its sibling species *E. andrei* Bouché, 1972, is the favoured species as it has wide environmental tolerances, high reproductive rates, good handling properties, will process most types of organic matter, and is the most studied in the literature.

Perionyx excavatus Perrier, 1872 "Indian Blue";

Eudrilus eugeniae (Kinberg, 1867) "African Nightcrawler";

Less commonly used species are:
Amynthas corticis (Kinberg, 1867) and *A. gracilis* (Kinberg, 1867) "Pheretimas" (formerly known a *P. hawayana*);
Eisenia hortensis (Michaelsen, 1890) and *Eisenia (=Dendrobaena) veneta* (Rosa, 1886) "European Nightcrawlers";
Lampito mauritii Kingerg, 1867 "Mauritius Worm".
At least four other candidate species have been recognized in Australia, these are *Anisochaeta buckerfieldi* (Blakemore, 1997), *Anisochaeta* spp. from Vict., Qld and NSW and *Dichogaster* spp. The vermicomposting potential of these species have not yet been rigorously researched.

Other worms involved in *vermi*composting are of Family Enchytraeidae (enchytraeid or pot worms), microdriles (small 'aquatic' worms), and nematodes (roundworms). Soils, of which composts are a richly organic subset, are highly diverse ecosystems with mineral, animal and plant components. Earthworms have a stimulatory effect on the other decomposer organisms by aerating the substrate, forming microclimates, and by producing biologically active casts.

Vermicomposting

The ability of composting species to do what they have always done best – these worms turn organic 'wastes' into fertilizer and protein - is being exploited commercially in various small to large-scale vermicomposting operations. Diverting landfill and recycling this valuable resource makes both ecological and economic sense, so-called 'Modern Alchemy'. Cornell University's Dr David Pimental puts the minimum benefit of this natural decomposer recycling at more than $760 billion per year worldwide. Recent studies have proved that casts contain enzymes (cellulase, proteinase, amylases, or phenyloxidases) and plant growth hormones (eg. cytocynins and auxins), while earthworm extracts have been found to have pharmaceutical potential with anti-viral and anti-cancer properties. However our knowledge of the processes involved is severely limited and there is little government funding for research: it is not known whether earthworms have the intrinsic ability to metabolize these compounds, or whether their microbial gut symbionts are the actual producers.

Compost worms will tackle all manner of organic wastes, and pathogen suppression has been reported after passage through the worm gut of the fecal coliforms, plant-pathogens, and of root-feeding nematodes, but again the mechanisms are not fully understood. After feeding, what comes out the south end of a compost worm wriggling northwards is microbially-activated, nutrient-enriched, granular, vermicast that, when added to crops as compost, can substantially increase yield and stimulate resident soil fauna, in particular the earthworking worms. The activities of microbes, fungi and invertebrates in the soil are responsible for decomposing carbon and nitrogen and making them available for plant growth. Pimental conservatively estimates the contribution of soil biota to agricultural topsoil formation at $25-50 billion each year, at the same time contributing to the rate of production and consumption of carbon dioxide, methane and nitrogen. But it is actually soil organic matter that is the major global storage reservoir for carbon.

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