Lumbricus rubellus **System:** Terrestrial

Kingdom	Phylum	Class	Order	Family
Animalia	Annelida	Clitellata	Haplotaxida	Lumbricidae

Common name red worm (English), red wiggler (English), leaf worm (English), angle worm (English)

Synonym *Allolobophora relictus* , (Southern, 1909)

Similar species

Summary Lumbricus rubellus is a medium sized epi-endogeic earthworm that is native to Europe. It is one of the most widespread earthworm invaders in the world and has invaded parts of Canada, United States, South America, Russian Federation and several sub-Antarctic islands. The combined impacts of this species and other exotic earthworms are having profound effects on forest ecosystems in North America, particularly in regions which lack native earthworms. Exotic earthworms rapidly consume leaf litter, thereby altering nutrient cycling and availability and other soil properties. This has cascading effects on microbial communities, invertebrates, vertebrates and seedling establishment, and may alter entire plant communities and threaten rare plant species.

view this species on IUCN Red List

Species Description
Lumbricus rubellus is a medium sized (10-15 cm) partially pigmented epi-endogeic worm. Mean biomass is reported to be 1.89 g (Wironen & Moore, 2006; Hendrix & Bohlen, 2002).

Uses
Lumbricus rubellus is an important commercial fishing bait species (Addison, 2009; Keller *et al*., 2007). It has also been identified as a potentially useful species for the breakdown of organic wastes. However it is a relatively slow growing species, and further research into its potential in vermicomposting is needed before its major adoption for this purpose (Edwards & Arancon, 2004).
In agricultural systems and natural systems adapted to earthworms, they provide important ecological services including improvement of soil properties (e.g. ., nutrient turnover, soil structure and water flow, pH, functional biodiversity, food sources for vertebrate predators) and increasing plant production. Indeed earthworms have been deliberately introduced to pastures, landfills and reclaimed mite sites in several countries around the world to improve agricultural productivity and minimise soil degradation (Baker *et al*., 2006).

Habitat Description
Lumbricus rubellus is common in coniferous forests in its native European and introduced North American range (Addison, 2009). It has also been documented to thrive in riparian zones characterized by high soil moisture and compacted soils, thought to present challenging conditions for earthworms (Costello & Lamberti, 2008).
It feeds on the surface litter but also burrows and produces casts in the upper mineral soil layer, and is found intimately associated with plant roots, suggesting that this species actively feeds in the rhizosphere (Hale *et al*., 2008). It is relatively frost tolerant (Tiunov *et al*., 2006), and thrives in soils with low pH (range 3.0-7.7) (Wironen & Moore, 2006).
Troglophilic (cave-dwelling) behaviour has been observed in *L. rubellus* in Alabama, Georgia, South Carolina and Tennessee (Reeves *et al*., 1999).

Reproduction
Lumbricus rubellus is not parthenogenic, and thus only reproduces sexually (Hendrix & Bohlen, 2002). Evans & Guild (1948 in Dymock *et al*., 1997) reported production of 106 cocoons/per individual in a laboratory culture.

Nutrition
Lumbricus rubellus is an epi-endogeic species. It inhabits and feeds in the litter and organically enriched surface layers of soil. Epigeic species facilitate the breakdown and mineralisation of surface litter (Hendrix & Bohlen, 2002). Epigeic species tend to possess more cellulase enzymes than anecic or endogeic earthworms, reflecting their diet of relatively undecomposed organic matter (McLean *et al*., 2006).
Earthworms, especially *Lumbricus* species have high calcium demands and strong litter calcium preferences (Reich *et al*., 2005 in Holdsworth *et al*., 2008). Their high calcium demands may be necessary to supply their well developed calciferous glands, which produce calcium carbonate that could moderate blood CO2 levels and pH when soil pCO2 levels are elevated (Holdsworth *et al*., 2008). Calcium content of litter is thus a predictor of litter preference among earthworms, and consequently decomposition rates and litter mass loss (Holdsworth, 2006 in Holdsworth *et al*., 2008).

General Impacts
In many ecosystems and in agricultural systems earthworms are highly beneficial to soil processes (Hendrix & Bohlen, 2002). However in forest ecosystems with few or no native earthworms, introduced species can have negative effects. Earthworms are keystone detritivores that can act as “ecosystem engineers” and have the potential to change fundamental soil properties, with cascading effects on ecosystem functioning and biodiversity (Frelich *et al*., 2006; Eisenhauer *et al*., 2007; Addison, 2009)
Exotic earthworms are a particular problem in previously earthworm-free temperate and boreal forests of North America dominated by *Acer*, *Quercus*, *Betula*, *Pinus* and *Populus* (Frelich *et al*., 2006).
Earthworms are often classified based on their activity and feeding type, which affects their impacts on the soil (Bouché, 1977 in Addison, 2009). *Dendrobaena octaedra* and *Dendrodrilus rubidus* are epigeic species, which inhabit and feed at the soil surface. Epigeics physically disrupt the organic layer of the soil by consuming and mixing the F and H layers, producing a homogenous and granular form of organic forest floor (Addison, 2009).
Lumbricus rubellus operates in two categories, 1) epigeic which inhabit and feed at the soil surface and 2) endogeic which live and feed in the mineral horizons below the organic (LFH) layer. Thus it is considered epi-endogeic in its habits, feeding on organic matter in the forest floor, but also mixing the organic material into the upper layer of mineral soil (Addison, 2009). *L. terrestris* is a deep-burrowing anecic earthworm, which create permanent vertical burrows in the mineral layer. They come to the surface to feed on litter and pull it down to their burrows, depositing casts of mixed organic and mineral material on the soil surface (Addison, 2009).
Thus earthworms in different functional groups have different impacts on the soil (Frelich *et al*., 2006; Hale *et al*., 2008). Often multiple earthworm species inhabit areas of forest, and studies suggest that impacts are greater when earthworms from more than one functional group occur together (Hale *et al*., 2005; Hale *et al*., 2008). Earthworm invasions typically occur in waves (e.g. Hendrix & Bohlen, 2002; Eisenhauer *et al*., 2007), with epigeic (e.g. *D. octaedra*, *D. rubidus*) or epi-endogeic (e.g. *L. rubellus*) species arriving first as they are able to utilise undisturbed forest floors. The first noticeable impacts tend to be physical disruption of the stratified humus layers on the forest floor. Endogeics generally only invade after the organic layer has been modified by epigeic or epi-endogeic species. Anecic species (e.g. *L. terrestris*) are usually last to arrive (James & Hendrix, 2004 in Addison, 2009).
The purported impacts of invasive earthworms are often varied between publications, and different soil types and soil layers may be affected differently by earthworm invasion. However the main effect of earthworms is to consume litter, and incorporate it into deeper soil layers, thus causing mixing of the A and O soil horizons. This causes extreme reduction of the litter layer and changes in nutrient concentrations and cycling in the soil. Other soil characteristics such as pH, porosity and decomposition rates may also be affected. Physical disruption of plant roots and mycorrhizal associations is also a common impact. These changes to fundamental soil properties have cascading effects on plant communities, microorganisms, micro and mesofauna, birds and mammals (Hale *et al*., 2008; Addison, 2009).
For a detailed account of the impacts of invasive earthworms please read Earthworms Impacts Information.

Management Info
There are currently no effective methods to eradicate established earthworm populations without unacceptable non-target effects. Thus the main technique for managing invasions is prevention of introductions, via various pathways (Cameron *et al*., 2007; Keller *et al*., 2007).
Preventative measures: One of the major pathways for earthworm introductions is believed to from release by anglers discarding unwanted live bait. Keller *et al*. (2007) suggest two alternatives to reduce the likelihood of further establishments while preserving the economically important live trade of earthworms. These are: 1) Replace the species currently sold with earthworm species that are unlikely to establish populations, e.g. *Eudrilus eugeniae* which has an extremely low invasion risk in the U.S. Midwest, and 2) Strengthen efforts to educate anglers to dispose of live earthworms responsibly, i.e. in the trash where landfill conditions are likely to kill them (Keller *et al*., 2007) or to prohibit the abandonment of live bait (Cameron *et al*., 2007).
Similarly, transport of cocoons and earthworms via vehicular transport is a major pathway for introduction to new locations. Thus construction of fewer roads, restricting the amount of traffic on roads or reclaiming roads where possible would minimize spread of earthworms (Cameron & Bayne, 2009).
Management and regulatory strategies should also take into account the fact that some earthworm species, such as *Lumbricus rubellus* have larger impacts than others. This species is less widely distributed than other exotic species. Thus preventing its introduction to new areas is important, even if those areas are already infested with other species (Hale *et al*., 2006). Similarly, some forests will be more susceptible to invasion than others. Litter calcium content is likely to be an important predictor of litter decomposition rates by exotic earthworms (Holdsworth, 2008).
Callaham *et al*. (2006) suggest various policy measures that could be adapted to prevent the spread of exotic earthworms. The authors suggest restrictions on transportation of soils from infested areas to non-infested areas, unless a special permit certifying that the material is free from earthworm propagules has been granted. Formalized earthworm introduction decision making tools are also recommended as an alternative to the *ad hoc* decisions made by regulating agencies at present. This decision-making process allows for the quarantine of materials containing propagules of earthworms that have not been identified or widely introduced previously. These quarantines would provide time to determine the ecological risk posed by the introduction of a given earthworm species into particular systems. Suggested types of information needed to determine ecological risk include mode of reproduction, number of embryos per cocoon, ecological “strategy”, and temperature, pH and moisture requirements (Callaham *et al*., 2006).
Cultural measures: Successful establishment of earthworm populations is influenced by management of the site. For example, synergistic effects of the invasive weed buckthorn and exotic earthworms could be minimized by early control measures to limit the weed (Heneghan *et al*, 2006).
Chemical control: Where non-native earthworms are not well established or are found in discrete populations, the use of chemical treatments to eradicate undesirable worms may be successful. Chemical control have been used in the management of golf courses. While these treatments are highly effective, the non-target effects of chemicals should be examined before large-scale utilization (Callaham *et al*., 2006).

Pathway
When Europeans first colonized the United States midwest they probably brought earthworms as adults or cocoons in dry ship ballast (Hendrix & Bohlen, 2002).Road vehicles are thought to be a major vector for the spread of earthworm cocoons (Cameron *et al*., 2008). Epigeic species are more easily transported in this manner as they are present close the litter surface (Cameron *et al*., 2007). In fac

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[1] GREAT LAKES
[1] RUSSIAN FEDERATION
[15] UNITED STATES

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