**Worms Make Risky Choices Too: The effect of starvation on foraging in the common earthworm, *Lumbricus terrestris***

<table>
<thead>
<tr>
<th><strong>Journal:</strong></th>
<th>Canadian Journal of Zoology</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Manuscript ID:</strong></td>
<td>cjz-2018-0006.R1</td>
</tr>
<tr>
<td><strong>Manuscript Type:</strong></td>
<td>Note</td>
</tr>
<tr>
<td><strong>Date Submitted by the Author:</strong></td>
<td>10-Apr-2018</td>
</tr>
</tbody>
</table>
| **Complete List of Authors:** | Sandhu, Pawandeep; University of Toronto - Mississauga, Biology  
Shura, Oskar; University of Toronto - Mississauga, Biology  
Murray, Rosalind; University of Toronto - Mississauga, Biology  
University of Toronto, Ecology and Evolutionary Biology  
Guy, Cylita; University of Toronto, Ecology and Evolutionary Biology  
University of Toronto - Mississauga, Biology |
| **Is your manuscript invited for consideration in a Special Issue?:** | Not applicable (regular submission) |
| **Keyword:** | common earthworm, *Lumbricus terrestris*, risk-taking, FORAGING < Discipline, life-history trade-offs, starvation |
Worms Make Risky Choices Too: The effect of starvation on foraging in the common earthworm, *Lumbricus terrestris*

P. Sandhu¹§, O. Shura¹§, R.L. Murray¹,², and C. Guy¹,² *

§ Authors contributed equally

¹Biology Dept., University of Toronto at Mississauga, 3359 Mississauga Road
Mississauga, ON L5L 1C6, Canada

²Dept. of Ecology and Evolutionary Biology, University of Toronto, 25 Wilcocks Street,
Toronto, ON, M5S 3B2, Canada

Pawandeep Sandhu¹: pawandeep.sandhu@mail.utoronto.ca

Oskar Shura¹: oskar.shura@mail.utoronto.ca

Rosalind L. Murray¹,²: rosalind.murray@utoronto.ca

* Corresponding author:

Cylita Guy

Dept. of Ecology and Evolutionary Biology, University of Toronto, 25 Wilcocks Street, Toronto,
ON, M5S 3B2, Canada

Tel: 647-886-9524

Fax: 416-978-5878

Email: cylita.guy@mail.utoronto.ca
Worms Make Risky Choices Too: The effect of starvation on foraging in the common earthworm, *Lumbricus terrestris*

Pawandeep Sandhu, Oskar Shura, Rosalind L. Murray, and Cylita Guy

**ABSTRACT**

Species should avoid risks to protect accumulated fitness. However, when faced with starvation, organisms may accept risks to enhance future reproductive opportunities. We investigated the effect of starvation on risk-taking behaviour in the common earthworm, *Lumbricus terrestris* (Linnaeus, 1758). *L. terrestris* are negatively phototactic annelids that feed on decaying plant matter at the soil surface. Feeding in high light conditions is a potentially riskier choice, given the threats of visual predators and desiccation. We predicted that starvation in earthworms would increase risk-taking behaviour and decrease time taken (latency) to make choices. We manipulated the starvation level of *L. terrestris* individuals (non-starved, half-starved, and full starved) and presented them with a binary foraging choice. Earthworms could choose either a low food/dark condition (low risk) or a high food/light condition (high risk). We found that starved individuals selected the high-risk condition more often than non-starved individuals. Starved individuals also had a decreased latency to first choice. Risk-taking did not scale with level of starvation; there was no difference in foraging choice and latency between the half and full starved individuals. Our results indicate that *L. terrestris* makes state-dependent foraging choices, providing insight into the importance of fundamental life history trade-offs in this understudied species.

**KEYWORDS**

earthworm, *Lumbricus terrestris*, risk-taking, foraging, life-history trade-offs, starvation
INTRODUCTION

Foraging presents a cost-benefit trade-off between growth and survival (Puvanendran and Brown 2002). Although necessary for energy acquisition, foraging can put organisms at a greater risk of predation (e.g. Kie 1999). Willingness of prey to take risks while foraging can be influenced by a variety of factors including age (Macri et al. 2002), reproductive status (Bunnefeld et al. 2006), food availability (Godin and Sproul 1988) and refuge location (van Oers et al. 2005). In particular, changes in risk taking can be strongly influenced by hunger level; when faced with starvation, a variety of taxa have been observed to take greater risks to obtain food (e.g. Lima 1998; Lima and Bednekoff 1999). For example, green sea turtles (Chelonia mydas Linnaeus, 1758) in poor body condition select higher-risk, but more profitable, microhabitats more frequently than turtles in good body condition (Heithaus et al. 2007). Piglets (Sus domesticus Erxleben, 1777), who are subject to accidental crushing by their mothers while feeding, also make risky choices to feed more often and for longer if in poorer body condition (Weary et al. 1996). Several theoretical foraging models (e.g. McNamara and Houston 1986; Brown 1988; Clark 1994) characterize the tradeoff between body condition and risk-taking in the context of protecting accumulated reproductive assets (i.e., ‘asset protection principal’ Clark 1994). While exposure to predators puts the entire reproductive asset at risk, starvation reduces the value of this asset, compromising future opportunities for fitness increases (Clark 1994). Animals in better body condition have accumulated fitness to protect. However, hungry individuals can be expected to accept predation risks to increase their reproductive value through increased body condition and, ultimately, enhance future fitness (Clark 1994). Risk-driven
flexibility while foraging, especially in relation to body condition, has been demonstrated in a variety of vertebrate taxa including: mammals (e.g. Hughes and Ward 1993; Berger-Tal et al. 2010), fish (e.g. Biro et al. 2005; Thomson et al. 2012), amphibians (e.g. Whitham and Mathis 2000), and birds (e.g. Macleod et al. 2005).

Numerous invertebrate species exhibit predator avoidance strategies that involve a trade-off between foraging and protection (e.g. Hernandez and Peckarsky 2014; Szokoli et al. 2015; Blubaugh et al. 2017; also reviewed in Scharf 2016), however, there are relatively few examples documenting state-dependent changes in foraging behaviour. Behaviours in response to predator stimuli, such as tube retreat in the polychaete worm *Serpula vermicularis* Linnaeus,1767 (Dill et al. 1997) and increased dispersal in the backswimmer *Notonecta undulata* Say, 1832 (McCauley and Rowe 2010), have been shown to limit foraging opportunities. Predator avoidance behaviours, and the potential food stress that may result as a consequence, creates a scenario in which these organisms may also be willing to make risky choices to increase foraging success. Schadegg and Herberholz (2017) demonstrated that in response to a visual danger cue, starved juvenile crayfish (*Procambarus clarkii* Girad, 1852) make the risky decision to freeze and remain near a food source, rather than fleeing. Additionally, in response to starvation, negatively phototactic arthropods (i.e., those that move away from light stimuli) display a decreased sensitivity to light (e.g. Shields and Wyman 1984; Dromph 2003), while some beetles spend less time engaging in anti-predator death feigning behaviour (Acheampong and Mitchell 1997; Miyatake 2001; Hozumi and Miyatake 2005). However, as indicated in a recent review examining the effects of starvation on arthropods (Scharf 2016), there is room to expand on these studies given the rarity of experiments combining hunger level and predation threat. This is
likely true for other invertebrate taxa, considering the existing taxonomic bias towards vertebrates and model organisms in animal behaviour research (Rosenthal et al. 2017).

We explore hunger-dependent risk-taking behaviour in the common earthworm, *Lumbricus terrestris* (Linnaeus, 1758). Earthworms are negatively phototactic (Parker and Arkin 1901), a behaviour known to be a predator avoidance strategy in other species such as the polyclad flatworm *Maritigrella crozieri* Hyman, 1939 (Johnson and Forward 2003) and the nematode *Caenorhabditis elegans* Maupas 1900 (Ward et al. 2008). Earthworms are also a primary food source for a diversity of predators including the red fox (*Vulpes vulpes* Linnaeus, 1758 - MacDonald 1980), the New Zealand flatworm (*Arthurdendyus triangulates* Dendy, 1895 - Boag and Yeates 2001), the European badger (*Meles meles* Linnaeus, 1758 - Roper 1994), and the carnivorous land snail (*Powelliphanta augusta* Walker, Trewick & Barker, 2008 - Boyer et al. 2011). Although many of these predators use a combination of vision and olfaction to locate or dig for *L. terrestris* at night (Macdonald 1983), when earthworms are most active (Michiels 2001), other predators such as birds may forage for earthworms at dawn (Macdonald 1983) or during the day (Macdonald 1983; Onrust et al. 2017). Thus, negative phototaxis may decrease *L. terrestris*’ risk of predation, especially from diurnal, opportunistic predators. Additionally, *L. terrestris* belong to a group of earthworms known as the anecic earthworms, which feed on decaying plant material at the soil’s surface, rather than in underground burrows (Scheu 2003).

This soil surface foraging behaviour may be risky for earthworms because it exposes them to potential predators. Although we speculate that the negative phototactic behaviour of *L. terrestris* relates to predator avoidance, it could also be adaptive for avoiding areas where high light causes arid soil conditions, putting individuals at a greater risk of desiccation. Regardless, the trade-off
that may exist between predator avoidance and soil surface foraging in *L. terrestris* makes them an ideal species to examine how starvation can influence risk-taking behaviour.

In addition to assessing starvation driven risk-taking behaviour in *L. terrestris*, we also characterize the time to first choice, or latency. Predation risk may be expected to impact not only the decision to forage, but other aspects of feeding behaviour as well, including food-handling time, acceptable size of prey items, and latency to foraging decisions (Cooper 2000). A negative relationship between latency to attack prey and hunger has been observed in bluntnose minnows (Morgan and Colgan 1987). Changes in latency to risk-taking behaviours have also been associated with changes in body condition (Martins et al. 2007) and stress hormones (Mathot and Dingemanse 2015). For example, in salmon (Reinhardt and Healey 1999) food-stressed individuals are faster (decreased latency) to engage in risk-taking foraging relative to individuals that are not food-stressed.

Beyond being a good system to examine hunger-dependent risk-taking behaviour, *L. terrestris*, like many earthworms found in northern North American forests, are an invasive species (Bohlen et al. 2004; Addison 2009; Craven et al. 2017). Considering that *L. terrestris* is one of the most prominent earthworm invaders in North America (Addison 2009), studying their behavioural ecology has implications for understanding their spread within ecosystems. Non-native earthworm species are ecologically destructive, driving changes in plant diversity and community composition, which may have lasting effects on proper ecosystem functioning (Bohlen et al. 2004; Craven et al. 2017). This highlights the need to manage the spread of these invasive species. Future management efforts would benefit from a greater knowledge of basic earthworm behavioural ecology, as understanding behavioural mechanisms can provide insight...
into ecological invasions (Holway and Suarez 1999; Sih et al. 2012) as well as potentially enhance models predicting invader spread (McTavish et al. 2013).

Considering the apparent ubiquity of state-dependent risk-taking in the animal kingdom, it is important to examine whether this behaviour applies broadly by testing it in non-traditional taxa. To our knowledge, no study has yet characterized starvation induced risk-taking behaviour in earthworms. Here, we performed a binary choice experiment to assess the effect of starvation on risk-taking behaviour in *L. terrestris*. We hypothesized that, as seen in a variety of other organisms and in line with theoretical expectations of fitness asset protection models (e.g., Clark 1994), an increased level of starvation would increase the willingness of *L. terrestris* to take risks to increase foraging success. Further, we predicted that latency to making risky foraging decisions would decrease as starvation level increased.

**MATERIALS AND METHODS**

We obtained *L. terrestris* individuals from a local bait shop; 15 were used in initial pilot studies and 54 were used in experimental trials (totaling 69 individuals). Worms were housed in groups of no more than 20 in plastic cylindrical containers filled with compost and covered with an opaque black cloth to prevent disturbance by external light. We created three experimental food treatments: non-starved, half-starved, and full-starved individuals. Non-starved worms were kept in high-nutrient compost for seven days prior to the experiment. Full-starved worms were kept in containers filled with low-nutrient potting soil for 7 days prior to the experimental trials. The starvation period was chosen based on the methods of Warne et al. (2001). Half-starved worms were kept in high-nutrient compost for four days and then transferred to low-nutrient
potting soil for three days prior to experimental trials (roughly half of the time specified by Warne et al. (2001)). The half-starved treatment was implemented to test for a threshold in the level of food stress necessary to cause a state-dependent reaction in *L. terrestris* individuals (similar to Morgan and Colgan 1987 and Dromph 2003).

Trials were conducted in a 25.4cm x 25.4cm x 5.08cm experimental arena divided into two 12.7cm x 25.4cm x 5.08cm sections. One section (half the arena) was layered with 1.9cm of low-nutrient potting soil, while the other half was layered with 1.9cm of high-nutrient compost (see supplementary material Figure S1). The low-nutrient section of the container was covered with a black opaque cloth to decrease external light, at a height of 2.54cm above the soil. A cardboard bridge, spanning the length of the container and covered with a layer of clear tape (3M Scotch Magic Transparent Tape; to prevent the worms from consuming the cardboard), was placed in the middle of the container to separate the low and high-nutrient sections. A LED lamp was set up 50.8cm above the container, shining directly on the high-nutrient side. Light from LED bulbs can be detected by *L. terrestris* (Ratner and Gardner 1968)), however LED lamps give off less heat relative to incandescent bulbs (Petroski 2002). As such, we used an LED lamp to decrease the potential effects of heat and soil moisture loss, and increase the likelihood that earthworms were responding to the light cue, rather than a combination of light and heat. The low-food (potting soil), dark side of the container was considered the low-risk choice, while the high-food (compost), light side was considered the high-risk choice.

We performed a pilot trial to test for an effect of mass on risk-taking behaviour in *L. terrestris*. We also used the pilot trials to assess the time necessary for a worm to evaluate both substrates and make a final choice (see supplementary material Table S2). Finally, we examined
if worms had a preference for the high nutrient compost used here as the high-food condition (see supplementary material Table S3). Our pilot data showed that mass did not affect an individual’s choice (see supplementary material Table S1) and was therefore not included in our future trials. We also found that 12 minute trials allowed for ample time to sample and choose one side/substrate (see supplementary material Table S2). Lastly, we confirmed that earthworm’s had a preference for the high nutrient compost (see supplementary material Table S3).

We conducted 18 trials in each of our three starvation conditions (non-starved, half-starved, and full-starved), with each worm being used only once. For each trial, individuals were placed in the center of the bridge and observed for a maximum of 12 minutes. During the observation period, we observed all animals sampling both substrates (high and low risk), possibly assessing soil quality through use of chemosensory organs. Earthworms are known to have a variety of sensory cells in the integument (Knapp and Mill 1971), some of which are involved in chemoreception (Syed et al. 2017). For each individual, we recorded final risk choice (high or low) and time to make a final choice (latency). Worms were considered to have made a final choice when their entire body was on one side of the experimental arena. We also recorded the location of the worm (low or high-risk section of arena) after the allotted 12 min trial length. Between trials, potting soil and compost were replaced and the taped cardboard bridge was wiped down with a wet towel.

Statistical Analyses

All statistical analyses were conducted in R (R Core Team 2014). We used the ‘car’ (Fox and Weisberg 2011) and ‘lme4’ (Bates et al. 2014) packages to fit statistical models. To test for
an effect of starvation treatment on an individual’s risk choice (high risk = high-food and bright, low risk = low food and dark), we fit a binomial generalized linear mixed model with risk choice (high or low) as the response, starvation treatment (non-starved, half-starved, or full-starved) as the fixed effect and ‘day’ as a random effect. We also tested for an effect of starvation treatment on an individual’s latency to make a choice regardless of the level of risk. We log-transformed the measure of latency (in seconds) to normalize the data and fit a linear model with latency as the response variable, starvation treatment (non-starved, half-starved, or full-starved) as the fixed effect, and ‘day’ as a random effect.

RESULTS

We found that half and full starved individuals were more likely to choose the high risk environment compared to non-starved individuals (Figure 1, Table 1). When we tested for an effect of starvation on latency to make a choice (either high risk or low risk) we found that non-starved individuals took longer to make a choice compared to the starved individuals (Figure 2, Table 2). There was no difference between the starvation treatments (half vs. full) in their latency to make a choice, but both starvation treatments were faster to choose than the non-starved individuals (Figure 2, Table 2).

DISCUSSION

State-dependent changes in risk-taking behaviour have been documented in a number of species. Here, we demonstrate that starvation alters risk-taking behaviour in the common earthworm *L. terrestris*. In line with our predictions, and the expectations of theoretical fitness
models of foraging (e.g. McNamara and Houston 1986; Brown 1988; Clark 1994), starvation resulted in *L. terrestris* individuals making riskier choices (Figure 1); starved earthworms were more likely to select the high nutrient, bright light condition than non-starved individuals (Figure 2). We also found that starved individuals, as predicted, had a decreased latency to their choice. Interestingly, although starved individuals made risker and faster choices than non-starved individuals, we find no evidence for a difference in risk taking or latency between our two starvation conditions (half and full starved). Our results provide strong support for the notion that starvation can mediate life history trade-offs, leading to increased risk-taking behaviour in the common earthworm *L. terrestris*.

There has been a vast amount of literature concerning risk-taking behaviour in animals, with numerous studies looking at the trade-off between feeding and predation risk (Lima and Dill 1990). The dependence of this trade-off on body condition has been demonstrated in a variety of vertebrate taxa (e.g. Hughes and Ward 1993; Biro et al. 2005; Mathot et al. 2015) and is in line with theoretical fitness models of foraging and asset protection (e.g. Clark 1994). Studies examining risk driven flexibility in foraging of invertebrates, although less common, also exist. For example, scorpions in poor body condition, despite the higher predation risk from nocturnal predatory birds, are more likely to forage on full-moon nights compared to high body condition scorpions (Skutelsky 1996). This trade-off has also been demonstrated in a variety of other invertebrate species including crayfish (Schadegg and Herberholz 2017), spiders (Walker and Rypstra 2003), mollusks (Zhao et al. 2011), and mayfly larvae (Kohler and McPeek 1989). The results of our study are consistent with the larger field: when challenged with starvation, *L. terrestris* are more likely to take risks to acquire necessary resources.
Here, we assume that the choice to feed in a high light environment is riskier for *L. terrestris* as it may increase detection by potential predators. We felt that this was a reasonable assumption given that *L. terrestris* is a negatively phototactic species and that negative phototaxis is a known anti-predator strategy in other groups (*e.g.* Johnson and Forward 2003; Ward et al. 2008). Further, in pilot studies for this experiment we found that well-fed earthworms have a preference for dark conditions when soil quality is the same (see supplementary material Table S4). Our results indicate that, as seen in other photophobic species (*e.g.* Shields and Wyman 1984; Dromph 2003), earthworms will tolerate light conditions when under food stress. Although we assumed that foraging in the light represented an increased risk of predation, it could also represent an increased risk of desiccation (we do though control for and minimize heat effects through use of an LED lamp). Future work should look to characterize risk taking in earthworms in response to a direct predatory cue (*e.g.* bird calls or feces of a known predator, see Walker and Rypstra 2003), and further examine the ecological conditions under which negative phototaxis may provide an adaptive benefit to *L. terrestris*.

Other factors associated with life-history trade-offs could also be important for mediating risk-taking behaviour and resource acquisition in *L. terrestris*. For example, temperature is associated with increased food intake in juvenile earthworms (Otto 1990), while litter type and conspecific population density have been shown to modify habitat selection in *L. terrestris* (McTavish et al. 2013). Although we tested for an effect of mass on risk taking in our pilot data, it is also possible that size (assessed with a metric other than mass, such as body length) and age may influence earthworm risk-taking behaviour. Previous work in fish suggests that smaller individuals are more willing to take risks than their larger counterparts (Reinhardt and Healey...
This size-mediated risk-taking behaviour has implications for both individual fitness and population composition (Pettersson and Bronmark 1993; Lima 1998), and could be important for understanding *L. terrestris* ecology. In addition to considering how size influences risk-taking, future work could also examine individual variation in behaviour (*i.e.* personality) in response to stress (*e.g.* as in Drent et al. 2003; Houslay et al. 2017). Interspecific variation in behavioural responses to stressors, such as food stress, can impact an individual’s fitness and by extension their success in a given environment (Sih et al. 2012). Considering that *L. terrestris* is a hugely successful invasive species (Addison 2009), studies such as these would expand on what little we know of the behavioural ecology of this species and could contribute to future management.

Our study demonstrates that starvation alters risk-taking behaviour in the common earthworm *L. terrestris*. Relative to non-starved individuals, starved earthworms select riskier environments for foraging and have a decreased latency to their foraging decisions. State-dependent trade-offs, made to maximize long-term fitness, have been observed in a variety of organisms (*e.g.* Hughes and Ward 1993; Berger-Tal et al. 2010; Thomson et al. 2012; Schadegg and Herberholz 2017). However, to the best of our knowledge we present the first evidence of state-dependent trade-offs in earthworms and one of the few examples in Annelida. The lack of studies concerning the effects of starvation on annelid foraging speaks to the taxonomic bias in animal behaviour research. A recent study by Rosenthal et al. (2017) quantifies the skew of this bias, indicating that the field has largely focused on higher order taxa leaving other groups, which account for proportionally more of the earth’s biodiversity, relatively understudied. While it remains unclear why such a strong bias exists (*e.g.* tractability of study systems, innate human
bias, easy study/capture), the authors call for a greater consideration of neglected taxa to help understand the scope and pervasiveness of commonly studied behaviours such as mate selection, predator avoidance, and foraging (Rosenthal et al. 2017). By characterizing an often-assumed common trade-off in an understudied species, our study helps to fill this gap by expanding our knowledge about the situations in which state-mediated trade-offs between foraging and predation may exist. As outlined above though, there are a variety of ways in which future work extending this study could enhance our understanding of earthworm behavioural ecology. Given the invasive nature of *L. terrestris* in North America, this could greatly contribute to their future management.

**ACKNOWLEDGEMENTS**

We would like to thank D. T. Gwynne and K. Williams for advice and mentorship during the development of this study and the University of Toronto Mississauga’s BIO318 class of 2017 for helpful feedback. We would also like to thank Susan Dixon for assistance managing lab space and resources.
REFERENCES


rainbow trout, _Oncorhynchus mykiss_: Do hunger and predation influence risk-taking


Table 1. Results from a binomial generalized linear model investigating the effect of starvation treatment on risk-taking behaviour in *L. terrestris*. Half and full starved individuals were more likely to choose the high risk, high food environment compared to fed individuals. *p* <0.05 was considered significant.

<table>
<thead>
<tr>
<th>Starvation Treatment</th>
<th>Estimate ± std error</th>
<th>z</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept (Full Starved)</td>
<td>-0.45±0.48</td>
<td>-0.94</td>
<td>0.35</td>
</tr>
<tr>
<td>Half Starved</td>
<td>-0.50±0.71</td>
<td>-0.71</td>
<td>0.48</td>
</tr>
<tr>
<td>Non-Starved</td>
<td>1.41±0.71</td>
<td>1.97</td>
<td>0.04</td>
</tr>
</tbody>
</table>
Table 2. Results from a linear model investigating the effect of starvation on latency to make a
decision (either high risk, high food or low risk, low food) in *L. terrestris*. Full and half starved
individuals were faster to make a choice (low latency measure) compared to non-starved
individuals. Latency (in seconds) was log-transformed prior to inclusion in the model. *p* < 0.05
was considered significant.

<table>
<thead>
<tr>
<th>Food stress treatment</th>
<th>Estimate ± std error</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept (Full Starved)</td>
<td>5.04±0.21</td>
<td>23.85</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Half Starved</td>
<td>0.37±0.29</td>
<td>1.25</td>
<td>0.22</td>
</tr>
<tr>
<td>Non-Starved</td>
<td>0.83±0.35</td>
<td>2.43</td>
<td>0.02</td>
</tr>
</tbody>
</table>
FIGURE CAPTIONS

Figure 1. The proportion of *Lumbricus terrestris* individuals that chose the high risk, high food environment (rather than the low risk, low food environment) across three starvation treatments. Non-starved individuals were significantly less likely than half and full starved individuals to choose the high risk environment ($p=0.04$). $n=18$ for each treatment group. Error bars represent 0.95 binomial confidence intervals.

Figure 2. Mean latency for *Lumbricus terrestris* to make a choice between a high risk, high food or low risk, low food environment across three starvation treatments: non-starved, half starved and full starved. Fed individuals took significantly longer than half and full starved individuals to make a choice ($p=0.02$). $n=18$ for each treatment group. Error bars represent standard error.
Figure 1. The proportion of Lumbricus terrestris individuals that chose the high risk, high food environment (rather than the low risk, low food environment) across three starvation treatments. Non-starved individuals were significantly less likely than half and full starved individuals to choose the high risk environment ($p=0.04$). $n=18$ for each treatment group. Error bars represent 0.95 binomial confidence intervals.

215x166mm (300 x 300 DPI)
Figure 2. Mean latency for Lumbricus terrestris to make a choice between a high risk, high food or low risk, low food environment across three starvation treatments: non-starved, half starved and full starved. Fed individuals took significantly longer than half and full starved individuals to make a choice (p=0.02). n=18 for each treatment group. Error bars represent standard error.