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## **Earthworms as a prey source for an insular *Thamnophis***

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9  
10  
11 **Abstract**

12 Insular organisms evolve in closed systems; thus, changes caused by introduced species can  
13 drastically change their ecology. Isle Royale National Park is a remote island in Lake Superior  
14 that, until relatively recently, was void of earthworms. Its two native natricine snakes are known  
15 to feed on earthworms on the mainland, but it has now been confirmed that Eastern Gartersnakes  
16 (*Thamnophis sirtalis*) are feeding on earthworms on Isle Royale. It is unknown how the new  
17 dietary source will impact the snakes on Isle Royale.

18  
19 **Keywords:** diet, Eastern Gartersnake, Isle Royale National Park, Redbelly Snake, *Storeria*  
20 *occipitomaculata*

21  
22 Insular organisms have evolved in isolation from conspecifics on the mainland and in  
23 allopatry with other species native to that island. Islands are excellent models for more complex

24 ecosystems and allow for a better understanding of predator-prey relationships because of the  
25 reduction of species (Simberloff, 1974).

26 Many islands around the world have evolved interesting snakes with unique life histories  
27 (e.g., King and Lawson 1997; Boback 2003; Shwiff et al. 2010; Portillo et al. 2019). Whether  
28 native or introduced, the insular snakes are subjected to other dynamics of the island, including  
29 the potential introduction of a new prey source (King et al. 2006). The introduction of invasive  
30 alien species often has dramatic effects on the ecosystem, especially islands (e.g., King et al.  
31 2006; Russell et al. 2017). Earthworms, which have become well-established, are not native to  
32 the upper Midwest, are believed that they arrived in the United States as early as the 1600s in  
33 potting soil or ship ballasts (i.e. Gailing et al. 2012). On average, most earthworms move less  
34 than 8 m a year, but they are spread by humans, ending up in more remote places because of  
35 their usage as live bait for fishing or decomposers for gardening. Estimates suggest about 268  
36 worms per square meter of soil and as many as 81.8 billion worms in Manistee County (3320  
37 km<sup>2</sup> in size) in the northern lower peninsula of Michigan (Freley 2021).

38 Earthworms can have extensive negative impacts in forested environments. They remove  
39 the surface plant litter rapidly, alter the understory vegetation and disrupt soil physiology  
40 (Craven et al. 2017; Hendrix and Bohlen 2002). Such changes drastically alter the ecosystem  
41 (Frelich et al. 2006), especially on islands where space is relatively limited.

42 It can be difficult to identify a worm to species unless able to count the segments between  
43 the start of the worm and the clitellum (band), measure the total length of the worm and the  
44 length from the start of the worm to the clitellum (band), and examine a picture of the underside  
45 of the worm - however, all are introduced species in the Upper Midwest. For example,  
46 Minnesota, United States, has at least 15 introduced species of earthworms. Ontario, Canada, has

47 19 confirmed invasive species. The last locations to experience the invasion of earthworms are  
48 islands, especially in the upper Midwest, including those in Lake Superior.

49 Even though earthworms are now widespread in the Upper Midwest and several snakes  
50 are known to feed on them, little work has been done to document this prey source. Here we  
51 confirm that snakes isolated on an island are utilizing earthworms as prey and establish baseline  
52 data for the study of this over the next few years.

53

## 54 **Methods**

### 55 *Study Site*

56 Isle Royale National Park, Keweenaw County, Michigan, United States (47.9763° N,  
57 88.9313° W), is a relatively remote island in western Lake Superior. It is located 29 km from the  
58 Minnesota shore, 90 km from the Michigan shore and 24 km from the Ontario, Canada, shore.  
59 Isle Royale was designated as a National Park in 1940 and 99% is federally protected wilderness  
60 to this day (NPS 2023). The surrounding waters of Lake Superior are vast and cold, making it  
61 impossible for many organisms to immigrate to or emigrate from the island.

62

### 63 *Study Species*

64 Isle Royale has two native species of snakes: Eastern Gartersnake (*Thamnophis sirtalis*  
65 (Linnaeus, 1758)) and Northern Redbelly Snake (*Storeria occipitomaculata* (Storer, 1839)). It is  
66 unclear how they came to the island, but both are well-established and widespread. *T. sirtalis* is  
67 most notable on Isle Royale for its highly variable color morphs (Mooi et al. 2011) but otherwise  
68 neither species has been well-studied in this environment. *T. sirtalis* has a wide diet including  
69 frogs and toads, rodents, small fishes and invertebrates such as slugs, and earthworms (Mullin

70 and Seigel 2009; Virgin and King 2019). *S. occipitomaculata* feed primarily on slugs and  
71 occasionally on earthworms (Virgin and King 2019).

72

### 73 *Procedure*

74 The following observation was made while visiting Isle Royale National Park. The snake was  
75 not captured or handled and digital documentation of the event was taken.

76

### 77 **Results**

78 On 23 June 2023, at 14:54 h, at the South Lake Descor Campground (47.969099, -  
79 80.975028), a small (presumably a 2022 neonate) *Thamnophis sirtalis* was found feeding on an  
80 earthworm (Figure 1-3). This represents the first photographed event of consumption by a snake  
81 on Isle Royale even though both native species of snakes are documented to feed on earthworms  
82 on the mainland.

83 (Figure 1)

84 There is a note of an Eastern Gartersnake (*Thamnophis sirtalis*) consuming a *Lumbricus*  
85 *terrestris* Linnaeus, 1758 in what was previously the Ransom settlement located on the  
86 northwestern side of the island near the current day Daily Farm campground (Adams 1909).  
87 During a visit to Isle Royale in July 2023, two large “nightcrawler” earthworms were found near  
88 Malone Bay. One was on the concrete platform of the duplex housing and the other was found  
89 under a log on the Ishpeming Trail near Siskiwit Lake.

90

### 91 **Discussion**

92 Earthworms, not native to the Upper Midwest of the United States, were presumably  
93 introduced to Isle Royale National Park in Lake Superior as byproducts from fishing in the area.  
94 At this time we do not know how the introduction of earthworms and their expansion of range is  
95 going to impact the two native species of snakes on Isle Royale. It has been proven in other  
96 systems that the introduction of an abundant prey source had led to increased body size and thus  
97 increased reproductive potential in another Natricine snake (King et al. 2006; Llewelyn et al.  
98 2010).

99 The presence and impacts of earthworms on the nearby Boundary Waters Canoe Area  
100 Wilderness on the border of Minnesota, United States, and Ontario, Canada, are well  
101 documented (Wellnitz et al. 2020). However, there is little information available on the presence  
102 of earthworms on Isle Royale and when they originally were introduced to the island.  
103 Additionally, in 2003, JMR was surveying for Eastern Gartersnake (*Thamnophis sirtalis*) on  
104 Sand Island in the Apostle Islands, Wisconsin, United States, which are also in Lake Superior.  
105 JMR recovered an earthworm in the regurgitation from a snake caught during an evening  
106 rainstorm. At the time invasive earthworms had not yet been documented for Sand Island in the  
107 Apostle Islands. Given the presence of earthworms on these islands in or near Lake Superior, it is  
108 not surprising that earthworms are present on Isle Royale.

109 As stated by Simberloff (1974), in reference to Isle Royale, it is the isolation of the island  
110 that leads to the reduced flora and fauna. This allows for observations to be more easily made in  
111 reference to how changes impact the ecosystem. If earthworms are widespread and abundant on  
112 Isle Royale, they may constitute an important food source for the snakes of Isle Royale. Further  
113 studies of the island should make an effort to document the presence of earthworms to species to  
114 understand how widespread and abundant the invasive species are.

115

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120

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213

214 **Figure 1.** Sequence of a juvenile Eastern Gartersnake (*Thamnophis sirtalis*) ingesting a non-  
215 native earthworm on Isle Royale National Park, Keweenaw County, Michigan, United  
216 States of America.