

Darwin’s Toxic Tropical Land Planarians invade California and Europe: New Records

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Abstract

Land planarians (Geoplanidae) represent the most specious group within the tricladid flatworms. They occur in moist habitats throughout the Neotropics (South America etc.). 180 years ago, Charles Darwin (1809–1882) published a research paper on the distribution, biology and taxonomy of Geoplanidae in Chile and Brasil, with the description of the type species *Geoplana vaginuloides* Darwin 1844. Here, we summarize our studies on the invasive tropical land planarians *Bipalium kewense* (found in Golden Gate Park, San Francisco, CA, USA) and *Obama nungara*, recently discovered in Germany (Regensburg, Munich and Freiburg i. Br.). With reference to Darwin’s pioneering work and reports in the literature, we describe the occurrence of the deadly natural toxin Tetrodotoxin (TTX) in *B. kewense* and related taxa. Finally, we document the feeding and reproductive behavior of (hermaphroditic) land planarians, and the role of TTX in the paralyzation of earthworms and other prey organisms. These voracious flatworms invade, attached to soil imported via the trade of exotic plants from their natural habitats, foreign ecosystems outside their South American/Asian home country.

Keywords: *Bipalium*, Darwin, Land Planarians, Invasive Species, Tetrodotoxin

Introduction

One hundred and eighty years ago, the British Naturalist Charles Darwin (1809–1882) published a research paper in the *Annals and Magazine of Natural History* entitled: “Brief descriptions of several terrestrial Planarians” [1]. In this report, the author, who in 1859 became famous for his book *On the Origin of Species* [2], compared the body shape, color and “manner of crawling and the track of slime which they (i. e., land planarians) leave behind” with that of “terrestrial gastropods” (i. e., land snails). Hence, Darwin was aware of the principal of convergent evolution long before he finally published his most famous “Species-book” [3,4].

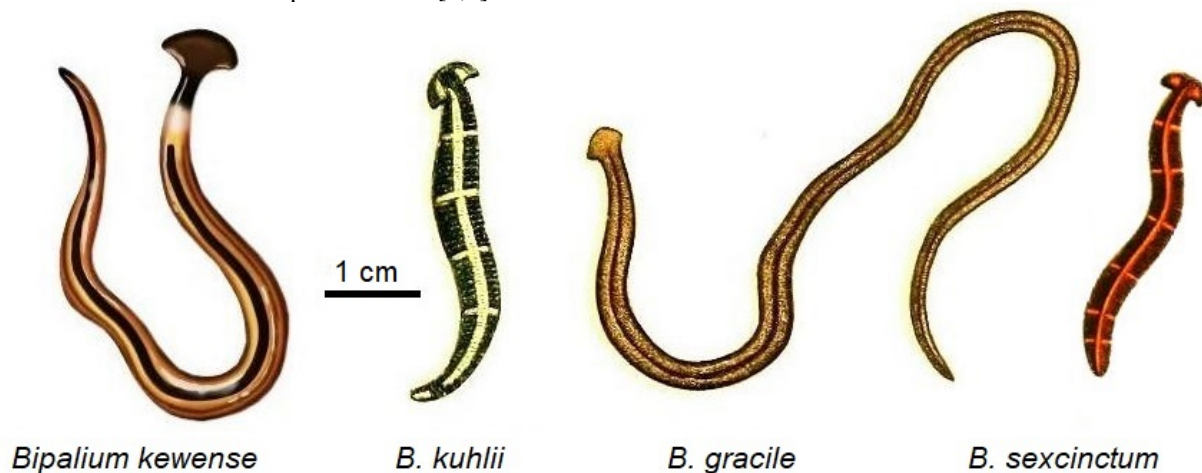


Fig. 1 Biodiversity of tropical hammerhead planarians (hermaphrodites) of the genus *Bipalium*: the invasive *B. kewense* Moseley 1878 and three other species. *B. kewense* produces a protective neurotoxin (TTX) to subdue its prey and, usually reproduces a-sexually via fragmentation and regeneration of juveniles (clones). (*B. kewense* after a drawing of Mesa Schumacher, 2021; the other species adapted from J. C. C. Loman, 1890).

In South America (Chile), Darwin [1] collected land planarians that “all belong to the genus *Planaria*”. Moreover, he wrote that they “live under stones,... and generally inhabit small sinuous chambers, like those frequently by earth-worms, in which they lie coiled and knotted up” [1]. This is another document for Darwin’s strong, life-long interest in earthworm biology, a topic to which he contributed his last book [5]. As a keen experimenter, Darwin kept some of his South American land planarians in a glass vial and observed that these animals avoid stagnant water as well as a dry ground: they prefer moist soil or rotten wood, where they flourish. Finally, it should be mentioned that Darwin observed the capacity to regenerate an intact “sister-individual” after cutting a land planarian into two pieces.

Recently, we observed and described the occurrence of the South American terrestrial flatworm *Obama nungara* from a soil sample in Regensburg, Germany [6,7]. In this article, we will report new discoveries of land planarians outside their home country and describe the toxicity of these up to 20 cm long worms that are voracious predators.

The Hammerhead Land Planarian *Bipalium kewense*

During the 1870s, when Charles Darwin was living (and working) as a private “senior scientist” at Down House (Kent, UK), a population of tropical land planarians of the genus *Bipalium* was discovered in a Greenhouse at Kew botanical gardens close to London. These “wandering” hammerhead worms were described as *Bipalium kewense* Moseley 1878, and represent one of the ca. 54 species known so far (the type species is *B. fuscatum* Stimpson 1857). Figure 1 shows this broad-headed tropical land planarian, together with three related species. The native area of *B. kewense* (Order: Tricladida, Family: Geoplanidae) is Southeastern Asia, i. e. the region from N-Vietnam to S-Cambodia.

Via the world-wide distribution of potted tropical plants (i. e., soil containing land planarians and/or cocoons), *B. kewense* reached the status of being the most widespread terrestrial flatworm. This up to 20 cm long invasive invertebrate has been discovered in 52 countries so far (the Americas, Caribbean, Asia, Africa, Australasia and Europe). One “hotspot” of the occurrence of *B. kewense* is the Golden Gate Park in San Francisco, California, USA. As recently noted by Agarval [8], “at least 12 species of non-native land planarians from around the world have been identified in the Bay Area” (region surrounding the S. F. Bay).

Numerous records of *B. kewense* from the G. G. Park (where the first author discovered/described the leech species *Helobdella carnifornica* Kutschera 1988 [9]) are listed in reference [8]. In 2018/19, when U. Kutschera was working as Scientific Advisor at I-Cultiver (then at Treasure Island in S. F.), the ecosystems of the G. G. Park were investigated (Fig. 2). In addition to many specimens of the “Golden Gate Leech *H. californica*” [9], several “Kew-hammerhead flatworms” (Fig. 1) were observed, usually under flowerpots (demonstrated by colleagues of U. K., i.e., biologists who studied this zoological “curiosity” of the Park). Hence, we can confirm that the G. G. Park in S. F. is definitively “infested” by imported hammerhead planarians, who feed on earthworms, snails, and other small land invertebrates.

In March 2024, Mori et al. [10] reported that this “Southeast Asian garden worm” was found on the island of Ischia (Campania, Italy). It follows that the cosmopolitan spread of this slimy hammerhead flatworm is an ongoing process that we can characterize as a severe “bio-invasion”.

The invasive Garden Flatworm *Obama nungara* in Germany

In 2008, first records of the occurrence of the South American terrestrial flatworm *Obama nungara* in Europe appeared in the scientific literature. Until March 2021, this ca. 4 cm long “garden flatworm” had been found in several areas of Southern Europe (France, Spain, etc.), but not in Germany. In April 2021, we received a soil sample from a garden in Regensburg (Bavaria, Germany). The person who send us this “worm” was convinced that it represents a specimen of the European land leech, a rare species about which Kutschera et al. had published a research paper [11]. After close inspection of this ca. 3–4 cm long invertebrate, we concluded that it is a member of the taxon *Obama nungara* sp. nov. Carbayo et al. 2016 [6,7]. Subsequently, we documented the presence of *O. nungara* in Germany (Fig. 3) and described details on its feeding behavior (prey organisms: earthworms, land snails, and aquatic planarians from German streams [6,7]).



Fig. 2 The Golden Gate Park in San Francisco, California. In different areas of this ecosystem, invasive tropical hammerhead-planarians (*B. kewense*) were discovered and observed by the first author of this report (see inset) (Original photographs of U. Kutschera, 2018, S. F., CA, USA).

In February 2024, it was reported in a German newspaper that the carnivorous flatworm *O. nungara*, which has in Europe no natural enemies, was found in the Elsass (Alsace, region in eastern France, close to the southern German border) [12]. With reference to statements of a biologist in Munich, Bavaria, it was reported that *O. nungara* has now been discovered in Botanical Gardens, attached to the soil and roots of imported tropical plants. In June 2024, a gardener in Freiburg i. Br. (southern Germany) informed us that he, as well as some colleagues, discovered *O. nungara* individuals associated with the soil of plants that were imported from France. Hence, this tropical “earthworm-killer” (Fig. 3) is present at least in three places of southern Germany (Regensburg, Munich and Freiburg i. Br.). Finally, it should be noted that the “Obama-flatworm” (name not related to a former US-President) has been found twice in the G. G. Park (Fig. 2), where the much larger “hammerhead garden flatworm” *B. kewense* regularly occurs.

Since land planarians prey on other, usually smaller Geoplanidae, there may be an ongoing “Darwinian Struggle for Existence” in the soil attached to the roots of imported tropical plants – in the G. G. Park, S. F./California, and in other places. Moreover, land planarians are cannibalistic invertebrates, so that members of the same (and other) species of the family Geoplanidae may be their worst enemies [10].

The Planarian-Neurotoxin TTX and struggle of earthworms to escape

In their article on the first record of *B. kewense* (Tricladida, Geoplanidae) in Ischia (Campanio, Italy), Mori et al. [10] speculate on the defense system of terrestrial flatworms with respect to predators as follows: “Other animals rarely devour land planarians, since surface secretions appear distasteful, if not toxic”. It has been known since Darwin’s time that some flatworms are toxic. However, the first scientific paper, wherein the occurrence of Neurotoxins in freshwater and marine planarians is documented, appeared decades later – in 1943 [13]. It took another 40 years until Tetrodotoxin (TTX) was discovered in marine flatworms. TTX is a deadly, natural low-molecular weight toxin that specifically blocks voltage-gated

sodium channels in nerve- and muscle cells, causing paralysis. TTX has been found in the ovaries and skin of Japanese pufferfish (genus *Takifuga*), amphibians (Salamandridae, such as newts of the genera *Taricha*, *Triturus* and *Ambystoma*; Anura, such as the tropical frog *Brachycephalus*), molluscs (Octopus *Hapalochlaena*), Echinodermata (Sea urchin *Echinus esculentus*), some annelids/arthropods – and marine bacteria [13].



Fig. 3 Unpublished Images of the invasive South American land planarian *Obama nungara*, discovered in the soil of imported flowering plants in Regensburg/Bavaria (Germany). Hungry specimen (left) and the same individual after feeding on an earthworm (right). (Original photographs of I. Ehnes and U. Kutschera, 2021, Germany).

In all of these animals (inclusive of land planarians), the toxin TTX functions as a chemical defense against predators and, in some cases, to prevent cannibalism by older conspecifics. Several studies have documented a positive correlation between the rate of survival and TTX-level in larvae or juveniles of a variety of species [13]. Ten years ago, Stokes et al. [14] confirmed the presence of TTX in the tropical land planarians *Bipalium kewense* (Fig. 1) and *B. adventitium*. These hammerhead garden flatworms are active earthworm hunters and sometimes attack prey organisms 100 times their own body mass. It has been observed that “The earthworm will often struggle violently to escape once the flatworm’s pharynx is expanded and attached...the earthworm seems to be paralyzed” [14]. Since TTX was found to be distributed throughout the body of the flatworm, it is obvious that “TTX is used during predation to subdue large prey items”, and that it protects the planarian against predators [14]. We observed a similar “earthworm-struggle for life” when *O. nungara* (Fig. 3) attacked/subdued their prey organism [6,7]. The question whether or not TTX is produced by *O. nungara*, and used by this “worm” as a natural “bio-weapon” during hunting/feeding is unanswered.

Conclusions: Darwin 1844 and a-sexual reproduction in Geoplanidae

Anti-evolutionists have repeatedly argued that Charles Darwin was “only” a theologian who published popular books on the atheistic-“God-less” origin of species [2,3,4]. Accordingly, his theory of descent with modification via natural selection is sometimes dis-regarded as pure speculation without a factual basis. Here we have shown that Darwin was not only an “Arm-chair-Theorist”. Rather, the British naturalist must be viewed as a dedicated “Hands-on-Biologist”, who studied animals (and plants) in nature, as well as in his private laboratory.

It has long been known that land planarians, like leeches [16], are hermaphrodites, i.e., they have male and female sex organs (testis or ovaries) in the same body. Most species, such as *O. nungara* (Fig. 3), reproduce sexually via copulation and the production of egg-capsules from which several juveniles hatch. However, the toxic hammerhead species *B. kewense* (Figs. 1,2) rarely develops mature sex organs to create egg capsules. Their main reproductive strategy is “a-sexual

fragmentation”, i.e., the individual creates “juveniles” via the break-up of the “parent-body” and subsequent regeneration of new, miniaturized planarians [15].

Finally, it should be mentioned that Darwin discovered in Rio de Janeiro (South America), under the bark of a decaying tree, a species that he described as “*Planaria vaginuloides*” [1]. In 2013, Carbayo et al. [15] published a revised taxonomy of the Geoplanidae. Under the headline “Genus *Geoplana* Simpson 1857”, the authors list as type species the taxon “*Geoplana vaginuloides* Darwin 1844” [15]. Hence, the man who became famous for his book “On the Origin of Species (1859)” [2] discovered/described, 15 years earlier, land planarians who “struggled to survive” via the production of anti-predatory toxins that may also help to subdue prey organisms via paralysis [14]. However, more work is required to further elucidate the occurrence and function of TTX in the more than 800 species of land planarians described so far [15].

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