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Anguillicola crassus

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Synonyms

Anguillicola crassus (Moravec et Taraschewski, 1988)

History and Risks

Species of the genus *Anguillicoloides* (syn. *Anguillicola*) are blood-sucking nematodes, parasitizing the swim bladder of eels of the genus *Anguilla* (Fig. 1). *Anguillicoloides crassus* is the most famous of a total of four different species. The parasite originates from the East-Asian and Australian region and was introduced to Europe in the early 1980s, probably by imported, infected Japanese eels *Anguilla japonica*. Afterwards, the nematodes spread across Europe with rapid pace often reaching infection rates of 80–100 % in almost all populations of the European eel *Anguilla Anguilla* (Fig. 1a). Later, the parasite has also been spread to America (1995) and Africa (2006). Recently, *A. crassus* has been listed as one of the 100 "worst" exotic species in Europe, not only because of the human-driven expansion but also due to its critically harmful potential in its new environment. Prevalences and intensities of infections by *A. crassus* are much higher in European eels than in Japanese eels and show an increased pathogenicity. The reason for this phenomenon is the missing immune response of European eels, while Japanese eels could acquire an immune defense during the coevolutionary process of parasite and host. This explains the Japanese eel's capability to fight and decompose histotrophic larvae (Fig. 1d) of the nematode parasite after vaccination or under high infection pressure.

The European eel has a high economic value since it is considered a culinary delicacy in many European and Asian countries, but since the end of the 1970s, the eel catch size in Europe has decreased by more than 75 %. There are several causes for the decline, e.g., due to strong anthropogenic pressures induced by fishing, pollutant levels, increasing habitat loss through engineering work on watercourses, as well as so-called turbine losses at hydroelectric power stations, but also natural causes, such as increased predation pressure by fish-eating birds (particularly cormorants) and diseases caused by viruses and especially debilitation caused by the invasive parasite *A. crassus*. High infection rates of *A. crassus* are causing an inflamed and plugged swim bladder and lead to significant impairment of the swimming ability of the eels, especially during the

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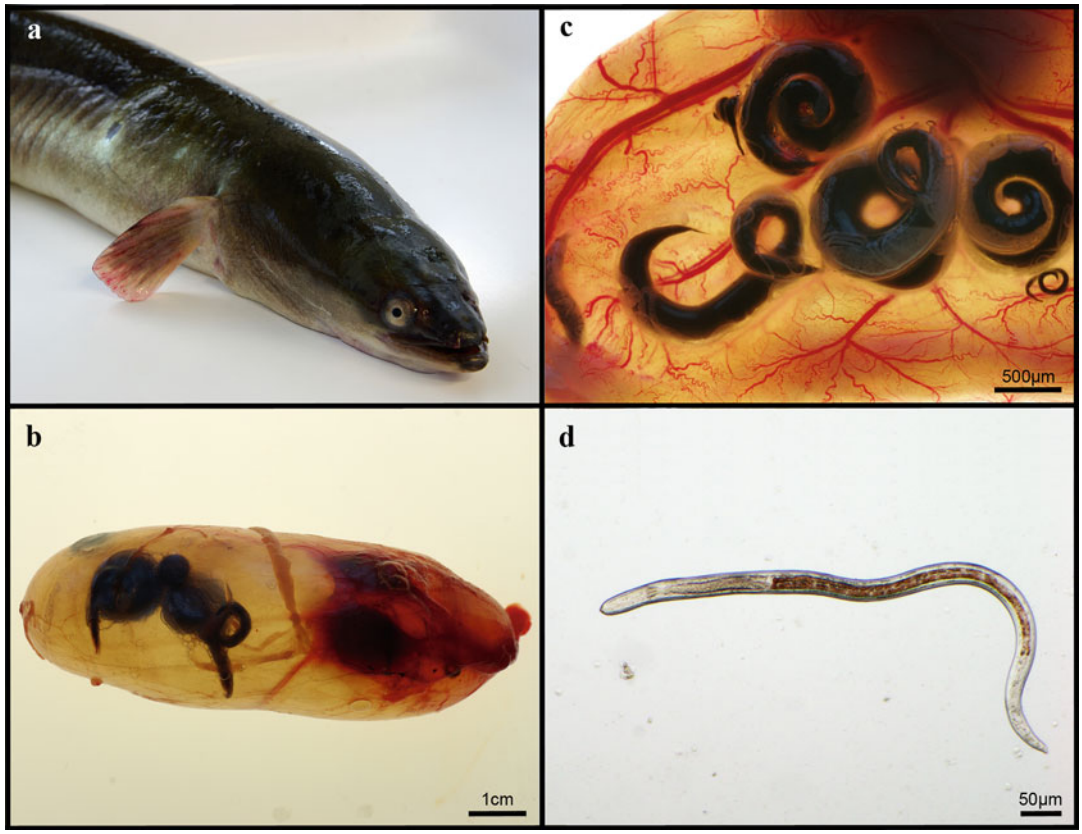
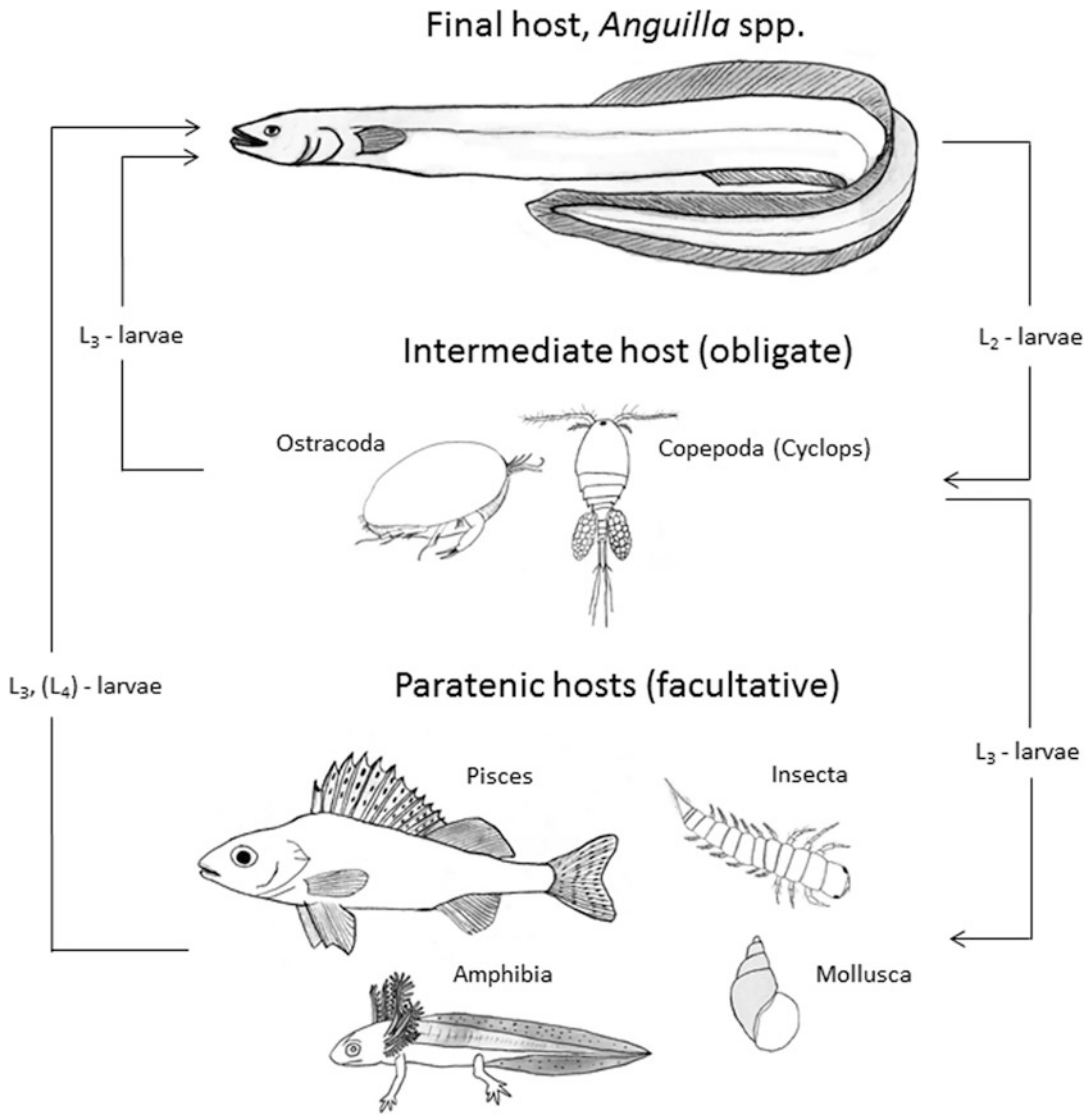


***Anguillicola crassus*, Fig. 1** *Anguillicoloides crassus*; (**a**) European eel *Anguilla anguilla*, the final host of *A. crassus*; (**b**) eel swim bladder of *A. anguilla* showing a typical number of adult blood-sucking *A. crassus*, which can cause heavy infections and might hamper the 5,000 km long spawning migration where they need to undertake diel vertical migrations (depths of 200–1,000 m). Additionally, a reduced gonad development was detected, which negatively affects the reproduction of European eel. Although there is a strong influence of anthropogenic factors in the distribution of the nematode, the successful spread of *A. crassus* can particularly be attributed to its generalist life cycle, including the incorporation of a broad variety of intermediate host species and a very high reproduction rate. 5,000 km long catadromous migration to the Sargasso Sea; (**c**) nematodes in swim bladder (opened up and well supplied with blood); (**d**) third-stage larvae of *A. crassus*, isolated from a paratenic fish host

Life Cycle of *Anguillicoloides crassus*

The life cycle of *A. crassus* (Fig. 2) has been well studied, both in Europe and in Asia. The adult, ovoviviparous nematodes are localized exclusively in the swim bladder of its final host *Anguilla* spp. (so far, six species of the genus A*nguilla* are documented to act as final hosts), where it feeds on blood and also reproduces. Each female lays several hundreds of thousands embryonated eggs, containing the second larval stage (L_2) (the first one (L_1) already developed in the uterus). The L_2-larvae leave the eel via the *ductus pneumaticus* of the swim bladder and the intestinal tract and thereby pass into the free water column. While most of the L_2-larvae hatch during the gut passage, some already



***Anguillicola crassus*, Fig. 2** Heteroxenous life cycle of *Anguillicoloides crassus*

hatch in the swim bladder where they occasionally penetrate the wall tissue and cause serve inflammation, which often lead to destructive lesions. In the water, the free-living L_2-larvae attract the first obligate intermediate host by wriggling movements. Until now, 17 different copepod and one ostracod species could be identified as first intermediate host. After penetrating the intestinal tract of the first intermediate host into its hemocoel, the nematode develops its third-stage larva (L_3) within a few days. This larval stage is already infective for the eel, including elvers (once they have left the sea) being susceptible at sizes of only 6–7 cm.

Additionally, different species of fishes (at least 37 fish species known, e.g., Eurasian ruffe *Gymnocephalus cernua*), mollusks (e.g., the snail *Galba corvus*), insects (e.g., the alderfly *Sialis lutaria*), and amphibians (e.g., the newt larvae of *Triturus vulgaris* or tadpoles of the fire-bellied toad *Bombina bombina*) can be incorporated in the life cycle of *A. crassus* as so-called

paratenic hosts. These hosts can accumulate multiple parasites of *A. crassus* (L_3-larvae mostly stop developing but sometimes develop into fourth-stage larvae) mainly in the body cavity and thus bridge the trophic levels between the larger piscivorous eels and the small copepods. Smaller eels get infected predominantly by feeding on parasitized first intermediate (obligate) hosts, e.g., crustaceans, whereas larger eels mostly prey on infective paratenic (facultative) hosts, e.g., fish or amphibians. Furthermore, a transmission from eel to eel (through cannibalism) is possible.

Once in its final host, the parasite larvae first perforate the eel's gastrointestinal tract and afterwards penetrate into the swim bladder wall by using a trypsin-like proteinase followed by a last molt into its L_4-stage. Both, the L_4 and the adult stage feed on eel blood (Fig. 1c). After an average of 8–10 months, *A. crassus* reaches sexual maturity and the life cycle restarts. While it takes *A. crassus* one year to complete its life cycle in the native range, it only takes an average of 8–10 months in the introduced range in Europe. Under optimal conditions of 20–21 °C water temperature it may even happen within only two months, which is likely to promote a faster spreading of the parasite.

Further Reading

Emde S, Rueckert S, Kochmann J, Knopf K, Sures B, Klimpel S (2014) Nematode eel parasite found inside acanthocephalan cysts–a "Trojan horse" strategy?. Parasite Vector 7(1):1–5

Moravec F (2013) Parasitic nematodes of freshwater fishes of Europe, 2nd edn. Academia Praha, Czech Republic, pp 264–284

Moravec F, Skorikova B (1998) Amphibians and larvae of aquatic insects as new paratenic hosts of *Anguillicola crassus* (Nematoda: Dracunculoidea), a swimbladder parasite of eels. Dis Aquat Org 34:217–222

Weclawski U (2012) Evolutionary divergence of *Anguillicola crassus*, an invasive parasitic swim bladder nematode of eels of the genus *Anguilla*. Dissertation, Faculty of Chemistry and Biosciences, Karlsruhe

Zander CD (1998) Parasit- Wirt-Beziehungen – Einführung in die ökologische Parasitologie. Springer Verlag, Heidelberg, pp 67–69