

‘Global worming’: first record of an epidemic of *Triaenophorus crassus* in a population of Arctic charr *Salvelinus umbla*

D. ACHLEITNER*[†], H. GASSNER* AND R. SCHABETSBERGER[‡]

*Federal Agency for Water Management, Institute of Water Ecology, Fisheries and Lake Research, Scharfling 18, 5310 Mondsee, Austria and [‡]University of Salzburg, Department of Organismic Biology, Hellbrunnerstr. 34, 5020 Salzburg, Austria

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In May 2005, an epidemic of the cestode *Triaenophorus crassus* occurred in the *Salvelinus umbla* population of Lake Grundlsee, an oligotrophic Austrian Alpine Lake. Based on catches with a standardized multi-mesh gillnet survey 53% of *S. umbla* were infected with up to 17 cysts of *T. crassus* per fish. This is the first documented record of an epidemic of this tapeworm in *S. umbla*.

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The Arctic charr *Salvelinus umbla* (L.) is a glacial relict species that was cut off from northern populations when glaciers retreated at the end of the last ice age. Landlocked stocks originally populated the lakes of the northern Alps, but the species was also transferred to water bodies south of the Alps as far as northern Italy (Doljan, 1920). Since medieval times *S. umbla* and whitefish *Coregonus* spp. have been the most important commercially exploited fish species in the Austrian lake district (Salzkammergut). Gassner *et al.* (2005) studied the fish communities of 43 lakes (>50 ha) in Austria and analysed all available historical documents recorded since the 13th century. *Salvelinus umbla* was classified as the sentinel (=characteristic) species in 16 lakes. Among all those water bodies the cold, oligotrophic and dimictic Lake Grundlsee (47°38' N; 13°52' E) harboured one of the most important *S. umbla* fisheries in the country, and the first records are from 1280 AD. In the mid 18th century, the stock almost collapsed due to over-exploitation, but catch restrictions allowed the population to recover (Wallner, 1911). During the 1970s, the average length of adult *S. umbla* decreased from c. 300 to 220 mm total length (L_T), probably due to eutrophication and mismanagement (Jagsch, 1987). For >700 years, however, no parasites have been reported in the flesh of *S. umbla*.

[†]Author to whom correspondence should be addressed. Tel.: +43 6232/3847-35; fax: +43 6232/3847-33; email: daniela.achleitner@baw.at

In May 2005, a large outbreak of the cestode *Triaenophorus crassus* occurred in the Lake Grundlsee. The life cycle of *T. crassus* requires predaceous copepods and usually coregonid fishes as intermediate hosts and the pike *Esox lucius* L. as the definitive host (Williams & Jones, 1994). Although the parasite does not affect humans, the flesh of infected *S. umbla* is classified as 'nauseous' by Austrian food law and cannot be marketed. On 15 June 2005, the *S. umbla* fishery was closed and remains so.

During the last century, the uncontrolled introduction of alien and translocated species increased throughout Europe, and natural fish communities were severely disturbed (Coxw, 1998; Zick *et al.*, 2006). Originally, only eight fish species occurred in the Lake Grundlsee [*S. umbla*, lake trout *Salmo trutta* f. *lacustris* L., minnow *Phoxinus phoxinus* (L.), Danube bleak *Chalcalburnus chalcoides* (Güldenstädt), European chub *Squalius cephalus* (L.), bullhead *Cottus gobio* L., burbot *Lota lota* (L.) and stoneloach *Barbatula barbatula* (L.)].

Esox lucius were reported for the first time in Lake Grundlsee in 1966, although no records of stocking were available. They reproduced successfully and a viable population has established. In the 1980s perch *Perca fluviatilis* L. was introduced, probably by anglers releasing live baitfish. About 10 years ago, *P. fluviatilis* numbers started to increase. Based on a standardized gillnet survey in 2003 (EN 14757, 2005) *P. fluviatilis* dominated the catch (94% numbers and 66% mass). Coregonids (*Coregonus* spp.) were stocked for the first time in the 1920s and irregularly throughout the second half of the 20th century, but in contrast to the other two species they did not reproduce within this cold, oligotrophic Alpine lake. Large specimens (>2 kg) are caught infrequently, but the reason for failing to establish viable populations remains unknown.

The fishery of the Lake Grundlsee is owned and managed by the Federal Forestry Agency. Besides one commercial licence, c. 60 angling licences are issued. *Salvelinus umbla* was the most important commercial species, and the yearly harvest was c. 1.4 kg ha⁻¹ (Total catch c. 600 kg).

To determine the degree of infection of lake fish with plerocercoids of *T. crassus*, a survey was carried out from 26 to 28 June 2005. Multi-mesh gill-nets were set randomly throughout the lake at 2–30 m (15 bottom-set nets, type Nordic, length 30 m, height 1.5 m and nine pelagic sets, type Nordic pelagic, length 27.5 m, height 6 m). In total, 2160 m² of net were fished for 432 h.

All fishes caught were determined to species level, weighed (*M*, g) and *L_T* measured to the nearest mm. The fishes were examined for plerocercoid cysts by cutting the fillets transversally into c. 5 mm thick slices. Otoliths (sagittae) were removed and ground for age determination.

Fulton's condition factor (*K*) was calculated as: $K = 10^5 \times M L_T^{-3}$.

Two hundred and forty-four fishes, belonging to six different species, were caught (*S. umbla*, *P. fluviatilis*, *C. chalcoides*, *L. lota*, *S. cephalus* and *Coregonus* sp.). *Salvelinus umbla* dominated the catch by number (48.0%) and mass (67.0%). The translocated *P. fluviatilis* were almost as abundant (41.8%). The remaining species constituted only 10.2% by number and 16.4% by mass.

Cysts with *T. crassus* plerocercoids were found only in the flesh of *S. umbla* and were externally visible as 10–15 mm diameter masses on the flanks of the fish (Fig. 1). *Salvelinus umbla* 130–390 mm *L_T* were caught and the dominant

L_T class was 240 mm. Fifty-three per cent *S. umbla* sampled were infected with *T. crassus*, with one to 17 cysts per fish (Fig. 2). The proportion of infected fish increased with L_T up to 350 mm. The few larger fish (>350 mm; $n = 2$) in the catch carried no plerocercoids (Fig. 3). No significant difference was found between the K of infected and uninfected fish (Mann–Whitney U -test; median = 0.78 both groups). Seventy-five per cent of fish of the age classes $\geq 5+$ years were infected with *T. crassus* (Fig. 4). Young fish (<130 mm) were missing from the catch. Previous results show their catchability was low, because young *S. umbla* stay hidden in gravel (Zick *et al.*, 2007). Preliminary data collected during 2007 indicate that infection rate had increased to >90%, and the maximum number of cysts per fish had risen to 29 (unpubl. obs.).

Triaenophorus crassus, for which *Coregonus* spp. are normally intermediate hosts (Miller, 1952; Dick & Rosen, 1982; Rosen & Dick, 1984; Pulkkinen & Valtonen, 1999), has occurred as an epidemic for the first time in *S. umbla*. So far, *T. crassus* plerocercoids were found only occasionally in *S. umbla* (Lawler & Scott, 1954). Both, *E. lucius* and translocated *Coregonus* spp. could have been the vectors introducing the parasite into Lake Grundlsee. *Coregonus* spp. may have consistently contaminated the lake with parasites until 1998, when stocking was finally abandoned.

Infected *S. umbla* had a remarkable appearance: clearly visible, large cysts were spread over their body (Fig. 1). Infected *Coregonus* spp. do not show these lumps, supposedly because their large scales cover the plerocercoids (Ulmer, 1971).

In *Coregonus* spp., *T. crassus* plerocercoids have a live span of several years (Miller, 1952; Rosen & Dick, 1984) and they accumulate with age (Pulkkinen & Valtonen, 1999). Consequently, older (>5 years) and longer (>210 mm) *S. umbla* carried more plerocercoids. The largest *S. umbla* caught contained no plerocercoids, but sample size was too low to conclude that large fish are not infected.

Infections with *T. crassus* are known to impair the growth of *Coregonus* spp. (Pulkkinen & Valtonen, 1999), and to cause serious damage in the muscles of



FIG. 1. Typical cysts with plerocercoids of *Triaenophorus crassus* (→) in the muscle tissue of *Salvelinus umbla*.

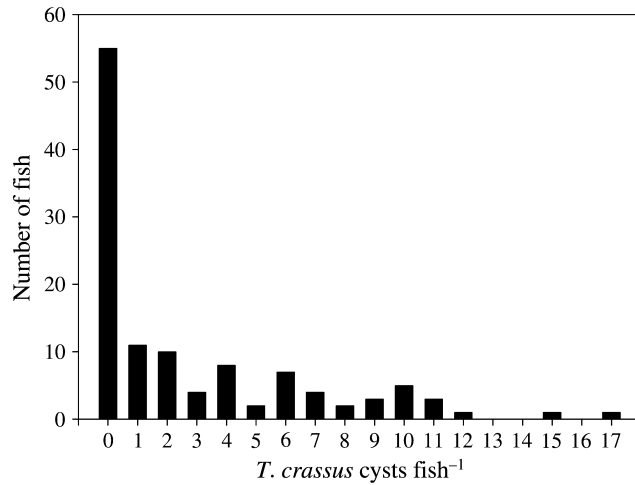


FIG. 2. Frequency of occurrence of *Triaenophorus crassus* cysts in *Salvelinus umbla* ($n = 117$).

experimentally infected fry (Dick & Rosen, 1982; Rosen & Dick, 1984). The growth and condition of *S. umbla* in Grundlsee may also have been affected, but a thorough analysis of glycogen or lipid contents of muscle tissue will be required to test for differences between healthy and infected fish.

Given the long tradition and the high value of the local *S. umbla* fishery, this epidemic has severe socio-economic consequences in the area. Not only had the commercial *S. umbla* fishery to be closed but also valued angling licences are no longer issued for this species. The debate about health risks for humans caused anxiety in the local community.

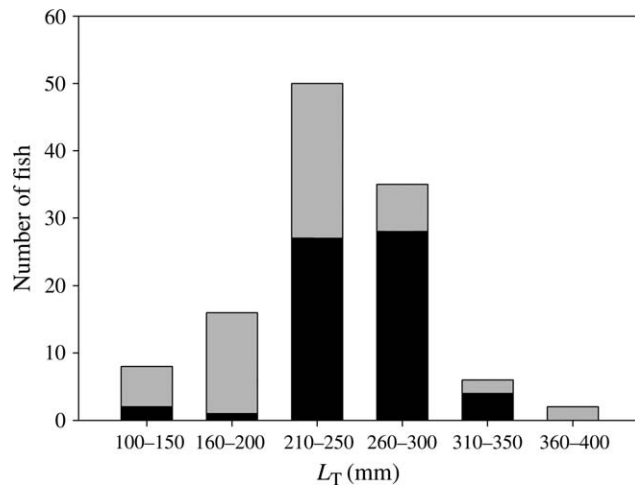


FIG. 3. Infection with plerocercoids of *Triaenophorus crassus* ($n = 117$) in relation to total length (L_T) of *Salvelinus umbla* (■, infected and □, uninfected).

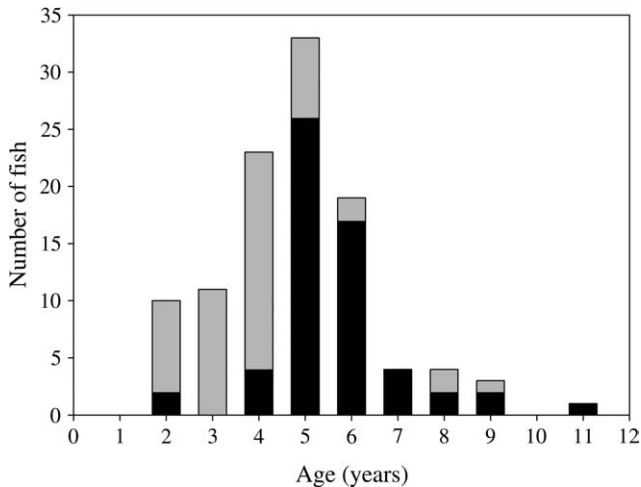


FIG. 4. Infection with plerocercoids of *Triaenophorus crassus* ($n = 109$) in relation to age of *Salvelinus umbla* (■, infected and □, uninfected).

The eradication of *E. lucius* will be a straightforward strategy to reduce the parasite populations, and it is already promoted by paying anglers for each fish. Nevertheless, as one adult cestode can release more than a million eggs (Bohl, 1966), it will take many years of intensive fishing to contain the epidemic. The ecosystem has been severely changed and may not return to the pristine conditions before the introduction of translocated fish species.

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References

- Bohl, M. (1966). Über das Vorkommen des Bandwurmes *Triaenophorus* (Forel 1868) in oberbayerischen Seen. *Allgemeine Fischereizeitung* **19**, 91.
- Cowx, I. G. (Ed.) (1998). *Stocking and Introduction of Fish*. Oxford: Blackwell Science.
- Dick, T. A. & Rosen, R. (1982). Experimental infections of whitefish, *Coregonus clupeaformis* (Mitchill), with *Triaenophorus crassus* Forel. *Journal of Fish Diseases* **5**, 83–86.
- Doljan, E. (1920). Der Seesaibling (*Salmo salvelinus*) und seine wirtschaftliche Bedeutung. *Österreichische Fischerei Zeitung* **17**, 86–104.
- EN 14757 (2005). *Wasserbeschaffenheit – Probenahme von Fisch mittels Multi-Maschen-Kiemennetzen*. Berlin: Beuth Verlag.
- Gassner, H., Wanzenböck, J., Zick, D., Tischler, G. & Pamminger-Lahnsteiner, B. (2005). Development of a fish based lake typology for natural Austrian Lakes >50 ha based on the reconstructed historical fish communities. *International Review of Hydrobiology* **90**, 422–432.
- Jagsch, A. (1987). *S. umbla* in some of the lakes of the Eastern Alps (Austria). Proceedings of the Fourth ISACF workshop on *S. umbla*, 1986. *ISACF Information Series* **4**, 64–72.
- Lawler, G. H. & Scott W. B. (1954). Notes on the geographical distribution and the hosts of the cestode Genus *Triaenophorus* in North America. *Journal of the Fisheries Research Board of Canada* **11**, 884–893.

- Miller, R. B. (1952). A review of the *Triaenophorus* problem in Canadian lakes. *Journal of the Fisheries Research Board of Canada, Bulletin* **95**.
- Pulkkinen, M. & Valtonen, K. (1999). Accumulation of plerocercoids of *Triaenophorus crassus* in the second intermediate host *Coregonus lavaretus* and their effect on growth of the host. *Journal of Fish Biology* **55**, 115–126.
- Rosen, R. & Dick, T. A. (1984). Experimental infections of rainbow trout *Salmo gairdneri* Richardson, with plerocercoids of *Triaenophorus crassus* Forel. *Journal of Wildlife Diseases* **20**, 34–38.
- Ulmer, M. J. (1971). Site-finding behaviour in helminths in intermediate and definite hosts. In *Ecology and Physiology of Parasites* (Fallis A. M., ed.), pp. 123–159. Toronto: University of Toronto Press.
- Wallner, J. (1911). Beiträge zur Geschichte des Fischereiwesens in der Steiermark. *Forschungen zur Verwaltungs- und Verfassungsgeschichte der Steiermark* **8**, 1–134.
- Williams, H. & Jones, A. (1994). *Parasitic Worms of Fish*. London: Taylor & Francis Ltd.
- Zick, D., Gassner, H., Filzmoser, P., Wanzenböck, J., Lahnsteiner, B. & Tischler, G. (2006). Changes in the fish species composition of all Austrian lakes >50 ha during the last 150 years. *Fisheries Management and Ecology* **13**, 1–9.
- Zick, D., Gassner, H., Rinnerthaler, M., Jäger, P. & Patzner, R. A. (2007). Application of size structure indices to Arctic charr *S. umbla* (L.) in Alpine lakes in Austria. *Ecology of Freshwater Fish* **16**, 54–63.