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SHORT COMMUNICATION

Tumour-like anomalies on copepods may be wounds from parasites

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Tumour-like anomalies have been reported from planktonic copepods, and these protuberances have been suggested to be cancer tumours or Ellobiopsid ectoparasites. However, endoparasites, such as Blastodinium, may also produce such protuberances that persist after the parasite has left its host.

During recent decades several groups of researchers have been puzzled by a variety of abnormal protuberances in planktonic copepods from marine and freshwater environments (Crisafi and Crescenti, 1975; Silina and Khudolei, 1994; Manca *et al.*, 1996; Omair *et al.*, 1999). There may be more than one causative agent for these reported anomalies, since they have been of different shapes and morphologies. Crisafi described abnormal, 'muff'-shaped formations emerging from the anuses of copepods from the Mediterranean Sea and from the Atlantic and Pacific oceans, and believed them to be a response to 'environmental pollution' (Crisafi, 1974). Furthermore, protruded tumour-like formations emerging from different points of the body of copepods were reported from coastal Italian waters (Crisafi and Crescenti, 1975). In the inner Baltic Sea estuary, Russia, and nearby lakes, high frequencies of tumour-like anomalies have been found on copepods and nauplii (Silina and Khudolei, 1994), and may be caused by pollution with carcinogenic agents. Unfortunately, that study did not present any information on the morphology of the observed tumour-like structures. Recently, large numbers of cysts and other anomalies have been found on zooplankton from the Laurentian Great Lakes, North America (Omair *et al.*, 1999; Bridgeman *et al.*, 2000). No definite explanation was given, but it was proposed that at least some of the observed structures were due to infestation by ellobiopsid parasites (Bridgeman *et al.*, 2000). A few of the abnormal copepod protrusions reported in the literature do resemble copepods that were damaged and degenerating at the time of fixation [Figs 1–4 of (Crisafi and Crescenti, 1975); Fig. 4 of (Omair *et al.*, 2001)]. In these cases, observation of live animals would have helped in the corroboration of the findings.

In an attempt to shed light on possible causes of such protuberances on copepods, live animals were screened for anomalies during a survey of zooplankton in the northwest Mediterranean, off Barcelona, Spain. Samples were taken as vertical tows from the bottom to the surface (depth 37–40 m) using a 100 μm mesh plankton net. Live samples were observed within a few hours after sampling, and pictures were subsequently made using Olympus dissecting microscopes or a Zeiss Axiovert microscope and a Canon G2 digital camera.

One type of protuberance observed was that shown in Fig. 1A. The appearance of the protuberance has some similarity with examples shown in Figs 6–8 of Crisafi and Crescenti (Crisafi and Crescenti, 1975) and Figs 1c and 1g of Bridgeman and colleagues (Bridgeman *et al.*, 2000). However, in Fig. 1A it seems as if the protuberance is continuous with an internal structure of the copepod, possibly the gut. A previous study has illustrated portions of the gut coming out of copepods (Crisafi, 1974), but all examples depicted in that study showed protuberances emerging from the anus, and must represent a different phenomenon.

In one case the gut of a protuberance-bearing copepod contained the dinoflagellate parasite *Blastodinium* sp. (Fig. 1B,C). At discovery, the parasite trophont was

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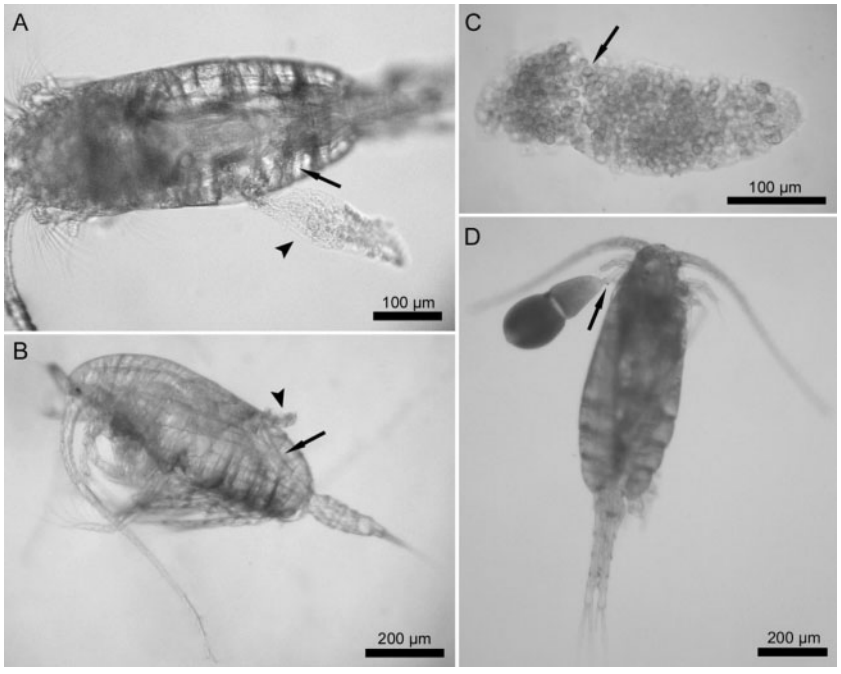

Fig. 1. (**A**) *Clausocalanus* sp. copepodite with a protuberance (arrowhead) penetrating its carapace. The protuberance seems to be continuous with the gut of the copepod (arrow). Formalin-fixed specimen collected in the northwest Mediterranean, July 2003. (**B**) *Clausocalanus* sp. (probably a c5 female) with a protuberance (arrowhead) caused by the parasite *Blastodinium* sp. shown in part C, which in this unusual instance has caused the gut (arrow) to penetrate through the host's carapace. Live specimen collected in the northwest Mediterranean, November 2003. (**C**) *Blastodinium* sp. trophont originating from the gut of the copepod shown in part B. The shape of the trophont is comparable with *B. cortortum*, but species determination is uncertain due to the poor condition of the specimen. The parasite was close to being mature and divided into free-swimming dinospores (arrow) 1 day after release of the trophont from the host. (**D**) *Ellobiopsis* cf. *fagei* on a *Pseudocalanus elongatus* female from the Bay of Biscay (East Atlantic). The parasite is attached by a well-defined stalk (arrow). Formalin-fixed specimen collected in May 2003.

located inside the protruding gut while the copepod was still alive and shortly afterwards, but before any picture was made, the parasite was 'released' (Fig. 1C). In the usual development of *Blastodinium* spp. in copepods, zoospores mature inside the copepod's gut and are then released as free-swimming cells that leave the host through its anus (Chatton, 1920). Usually, the host is not obviously physically damaged by *Blastodinium* parasitism and this, therefore, represents a deviation in the life cycle of *Blastodinium*, which is probably caused by abnormal development of the parasite or a particularly weak host. A similarly deviating development has been observed in another parasite of copepods, *Paradinium* sp. This species also usually releases zoospores through the anus of its hosts, but on rare occasions the zoospores emerge from the copepod through the exoskeleton (Chatton, 1920). The latter led to the description of the genus *Atelodinium* (Chatton, 1920), which was later synonymised with *Paradinium* (Chatton and Soyer, 1973).

Such abnormal infection by *Blastodinium* may explain some of the protuberances observed on marine copepods, but for freshwater copepod protuberances other explanations must be searched for, since this parasitic genus has so far been found only in marine environments (Chatton, 1920). The cyst-like anomalies in freshwater copepods from the Laurentian Great Lakes were suggested to be ellobiopsid parasites (Bridgeman *et al.*, 2000). This was stated to be the second report of an ellobiopsid parasite from fresh waters, the first one being from Lake Midmar, South Africa (Rayner and King, 1986). Three ellobiopsid species, all belonging to the genus *Ellobiopsis*, are known to infect marine copepods (Boschma, 1959) upon which they are found attached to antennas or on or near the feeding appendages. The three species of *Ellobiopsis* all share a characteristic morphology with a well-defined stalk, a trophomere and a gonomere (Steuer, 1932; Hovasse, 1951; Fig. 1D). The 'cysts' reported from Laurentian Great Lakes, on the other hand, had only vague characteristics and protruded between somites of the exoskeleton (Bridgeman *et al.*, 2000). It is, therefore, not any of the known *Ellobiopsis* species. A similar conclusion must be drawn concerning the first ellobiopsid-like parasite identified (Rayner and King, 1986). The two examples above are, thus, not *Ellobiopsis*, but could represent genera of copepod-infesting ellobiopsids that have yet not been described. This is, however, in need of verification; for

example. by studying the parasite developing on a live host or by studying the genetic material of the protuberances. Based on the structure of ellobiopsid-like protuberances alone it is difficult, if not impossible, to demonstrate an affiliation to the ellobiopsids unless the characteristic traits are well preserved. It has been suggested that some of these cyst-like structures found on copepods might be wounds induced by parasites rather than being the parasites themselves (Bridgeman *et al.*, 2000). The present report confirms this theory as one possibility for such anomalies. However, the possibility also exists that these anomalies are injuries from predator attacks, a phenomenon yet to be described for the copepods.

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