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A crab with three eyes, two rostra, and a dorsal antenna-like structure

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ABSTRACT

We describe a malformed specimen of the freshwater crab *Amarinus lacustris* from New Zealand. With three eyes in a horizontal row, two rostra, and a dorsal antenna-like structure, the pattern of malformation of this animal is unique and has not been described before. A careful inspection and description of external and internal structures, in particular the central nervous system, were carried out. These revealed, in addition to the external abnormalities, a retarded brain with a hypertrophied and backwards bent protocerebrum connected with all three eyes and putatively with the dorsal antenna-like structure. Based on these data, a variety of hypotheses about the causes for this kind of malformation are discussed. A scenario combining a conjoined twin (Duplicitas anterior) based on the duplication of the embryonic anterior head lobes and a regeneration event leading to the replacement of an eye by an antenna shows the best fit to the observed patterns.

1. Introduction

Naturally occurring malformations are not very frequent in Crustacea. Nevertheless, during the last 260 years or so a number of reports have accumulated in which a variety of patterns has been described. As with all malformations, unusual crustacean morphologies have always attracted human curiosity and interest. Accordingly, malformed crustaceans are found in old natural history collections and "Wunderkammern" (curiosity cabinets) (e.g., Martin, 2010) and today in the internet (e.g. http://newswatch.nationalgeographic.com/2013/09/12/how-did-odd-lobster-get-six-claws/visited 15th October 2013). The first account, to our knowledge, dates back to Rösel von Rosenhof (1755). Since then, the causes leading to these malformations have been analysed and/or experimentally studied in some cases, but our understanding of the mechanisms in terms of gradients, gene expression, and physiology are still in its infancy (see Shelton et al., 1981; Liubicich et al., 2009; Pavlopoulos et al., 2009). Aberrant structures have been described in embryos, larvae and adult crustaceans. Apparently, most malformations are not mutants at the genetic level but are caused by chemical and/or mechanical perturbations during development or regeneration. Most cases of observed and described aberrant structures relate to crustacean appendages. These show various degrees of loss, fusion, or multiplications of branches or appendage segments (e.g., Rösel von Rosenhof, 1755; Bateson, 1894; Przibram, 1909, 1921; Zalpeter, 1927; Nickerson and Gray, 1967; Gray, 1968; Riedl, 1975; Carmona-Suarez, 1990; Nakatani et al., 1997; Hoch and Yuen, 2009). The most famous of these appendage aberrations are the so-called *Bruch-dreifachbildungen* (Przibram, 1921) (triplication of structures after damage), often found at the claws of decapod crustaceans (see Shelton et al., 1981; Nakatani et al., 1998) and reported already form the Early Jurassic (Schweigert et al., in press). Furthermore, homeotic alterations such as antennae at the position of eyes (Bateson, 1894; Herbst, 1896, 1899; Maynard and Cohen, 1965; Sandeman and Luff, 1974; Riedl, 1975; Ravindranath, 1978; Nevin and Malecha, 1991), clawed maxillipeds (Bateson, 1894), and other limb types in "wrong" places (Zalpeter, 1927; Gordon, 1963; Fausto-Filho and Costa, 1977) have been reported. Trunk anomalies are comparatively rare. These relate to asymmetries, to missing or partly fused segments and hypertrophied segments (Bateson, 1894; Manning, 1962; Henry, 1966; Fausto-Filho and Costa, 1977; Araújo and Santos, 2012) or to the interesting phenomenon of spiral segmentation (Linder, 1947, 1952; Keilbach, 1958; Hernandorena, 1993). A special case are intersexes and gynandromorphs which show a combination of transformed appendages, in particular, gonopods and segmental structures such

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[1] It is our sad duty to announce that our esteemed colleague Stephen Moore, who discovered this little crab, died during the final production of this article.

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as gonopores (e.g., Bergendal, 1888; Turner, 1924; Farmer, 1972; Rudolph, 1995; Ahyong and Ng, 2008; Rudolph and Verdi, 2010; Martin and Scholtz, 2012), although these may also be due to sex-change transitions. The most dramatic malformations concern the duplication of parts of the longitudinal body axis that leads to the occurrence of conjoined twins (Brightwell, 1835; Reichert, 1842; Ryder, 1886; Herrick, 1895, 1909; Chatton, 1909; Pérez and Basse, 1928; Reinhard, 1954; Zipf, 1956; Williams, 1988; Harzsch et al., 2000; Jara and Palacios, 2001; Harlioğlu, 2002; Alwes and Scholtz, 2006; Rudolph and Martinez, 2008; Scholtz, in press.). There are a number of instances from embryos and larvae of crustaceans in the literature showing two heads, known as Duplicitas anterior in vertebrate anatomy or two trunks, the characteristic Duplicitas posterior, and a partial fusion (Alwes and Scholtz, 2006). In contrast, we know of only three published cases dealing with adult conjoined twins among crustaceans (Pérez and Basse, 1928; Reinhard, 1954; Williams, 1988; for review see Scholtz, in press). These are examples of a Duplicitas anterior showing paired anterior regions connected to one posterior body part. The rarity of adult conjoined crustacean twins might be due to complications associated with hatching, molting, and/or on their low general fitness. Moreover, most published descriptions of conjoined twins deal with decapod crustaceans. This bias perhaps can be explained by the extensive commercial and scientific interest in these crustaceans.

Here we report on a specimen of the freshwater crab *Amarinus lacustris* (Chilton, 1882) (Hymenosomatidae) from New Zealand which shows a hitherto unknown malformation. It possesses three compound eyes and a third antenna-like structure on the back of its carapace. We describe the pattern of this animal in detail and suggest scenarios that might have caused this pattern.

2. Material and methods

2.1. Animals

The two specimens of *Amarinus lacustris* (Chilton, 1882) examined were collected in North Island of New Zealand. For preservation and storage, they have been transferred to 70% ethanol. They (in the case of the malformed specimen the histological sections) are deposited in the Zoological Reference Collection of the Raffles Museum of Biodiversity Research (ZRC) at the National University of Singapore.

The malformed specimen (ZRC) was found by Stephen Moore in Hoteo River on 17th April 2007 (GKM sample, site 4). It was collected from a river that feeds into Kaipara Harbour, north of Auckland's Manukau and Waitemata Harbours. *Amarinus lacustris* is common in a number of streams and rivers of the Auckland and Waikato Regions and all specimens collected thus far have been normal. The normal specimen for this study (ZRC, 2010.0238) was collected at the 18th July 2008 in Waitakere, Oratia Stream. The species is known only from New Zealand and southern Australia including Lord Howe and Norfolk islands (Lucas, 1980).

2.2. Microscopy and photography of external structures

Observation and pictures were done with a Leica MZ12 stereomicroscope with digital camera (DC500) and with a Zeiss Lumar stereomicroscope equipped with epifluorescence and digital

Fig. 1. Photomicrographs of the malformed *Amarinus lacustris* specimen from various angles showing the overall appearance, the three eyes and the dorsal antenna-like structure.