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CORAL BLEACHING RECORDED DURING THE LITTLE ICE AGE

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ABSTRACT: When corals are exposed to stressors such as high solar radiation, sedimentation, pollution, reduced salinity or when water gets warmer or colder than normal, the corals expel the symbiotic algae and, consequently, get bleached. It is widely believed that coral bleaching is a phenomenon first observed less than 50 years ago. However, coral bleaching was first observed more than 150 years ago by Eugen von Ransonnet, during the period called the little ice age (*ca.* 1300 – *ca.* 1900). This neglected report is highlighted here. Clarification of past-time coral symbiont types could be done by the use of sequencing ancient DNA from old coral specimens in museum collections.

Keywords: coral bleaching, little ice age

INTRODUCTION

Hermatypic corals live in well-lit, nutrient-poor water and form the tropical and subtropical coral reefs (Goldberg 2013; Sheppard *et al*. 2017; Stanley and van de Schootbrugge 2018). Symbionts of the dinoflagellate genus *Symbiodinium*, called zooxanthellae, supply the coral with 79–135 percent of the energy it needs (Davies 1991; Sheppard *et al*. 2017). The symbiont pigment contributes to the coral polyp colour (Cabioch *et al*. 2010). Previously, it was believed that only one species of *Symbiodinium*, first described in 1962, was utilized by all corals and some other organisms (Rees 1966). Now we know that there are at least 22 *Symbiodinium* species (Guiry and Guiry 2019) and numerous varieties, which all have different biology and tolerance limits to environmental parameters such as light, eutrophication - and in particular temperature (Cantin and Spalding 2018; Quigley *et al*. 2018). When the coral is exposed to stressors such as high solar radiation, sedimentation, pollution, reduced salinity or when water gets warmer or colder than normal, these algae become toxic within the polyp (Morrow *et al*. 2018). The coral then expels the algae and, consequently, gets bleached (Morrow *et al*. 2018; Oakley and Davy 2018). Coral bleaching can cause death of the coral, but often it again takes up other symbionts that are better adapted to the altered environmental conditions, and not being toxic, so the coral is able to regrow (Coles and Brown 2003; Gilmour 2013; Ridd 2017). This is an adaptive strategy developed during millions of years (Lipps and Stanley 2016; Stanley and van de Schootbrugge 2018). The existence of numerous species of *Symbiodinium* allows the coral to adapt without changing its genetics (Edmunds 2014). Consequently, the same coral species can have different thermal tolerance in different geographic regions with different water temperature (Coles 1976; Jokiel and Coles 1990).

Coral bleaching was first observed in 1981 according to Veron (2008) and many others. However, this phenomenon was also reported earlier but little or no attention was given to it. Yonge already in 1931 found that living corals on the Great Barrier Reef were bleached after being exposed to high temperature (Oliver *et al*. 2009; Yonge and Nicholls 1931), and Kamenos and Hennige (2018) recorded the traces of coral bleaching in coral rock cores from the Great Barrier Reef back to 1575. So, coral bleaching is a phenomenon that always has existed as a normal way of adaptation to changing water temperatures, and is not a modern phenomenon.

MATERIAL AND METHODS

Eugen Freiherr von Ransonnet-Villez (1838–1926) was an Austrian diplomat, painter, lithographer, biologist and explorer (Durstmüller 1983). He contributed to the development of the illustration method called colour lithography and constructed a diving bell (Fig. 1) that was used during his studies of coral reefs in the Red Sea and in tropical Asia (Ransonnet 1863; 1867; 1876). Ernst Haeckel (1834–1919) was a German zoologist, professor in Jena, who among many other things promoted and popularised Charles Darwin's theory of evolution in Germany. Both scientists used different methods when studying living corals. Haeckel (1876) used a small boat with local divers and studied the corals in large glass jars. Ransonnet used a diving bell specially designed for making drawings under water, as well as studies in aquarium. He was very well aware of, and wrote about (1867) how colours changed by depth and distance under water.

RESULTS

Ransonnet visited the coral reefs at Tor, Egypt, on the western coast of the Sinai Peninsula (Fig. 2) in 1862 and included two large and detailed colour lithographs in his article (Ransonnet 1863). Both exhibit the phenomenon coral bleaching (Fig. 3a–b). In 1873 Ernst Haeckel (Haeckel 1876) visited the same coral reef as Ransonnet did and commented on his results: Die beiden von Ransonnet gegebenen Korallen-Meerschaften von Tor sind im Maassstab zu klein und in den Farben viel zu matt. Ich habe versucht, auf Taf. III die Farbenpracht derselben etwas intensiver auszudrücken. In English the text is: "The two coral seascapes from Tor given by Ransonnet are too small in scale and far too dull in colour. I have tried to express the splendour of the colours a little more intensely on plate III" (Fig. 4). So, Haeckel did not report any signs of coral bleaching during his field study 11 years after Ransonnet's.

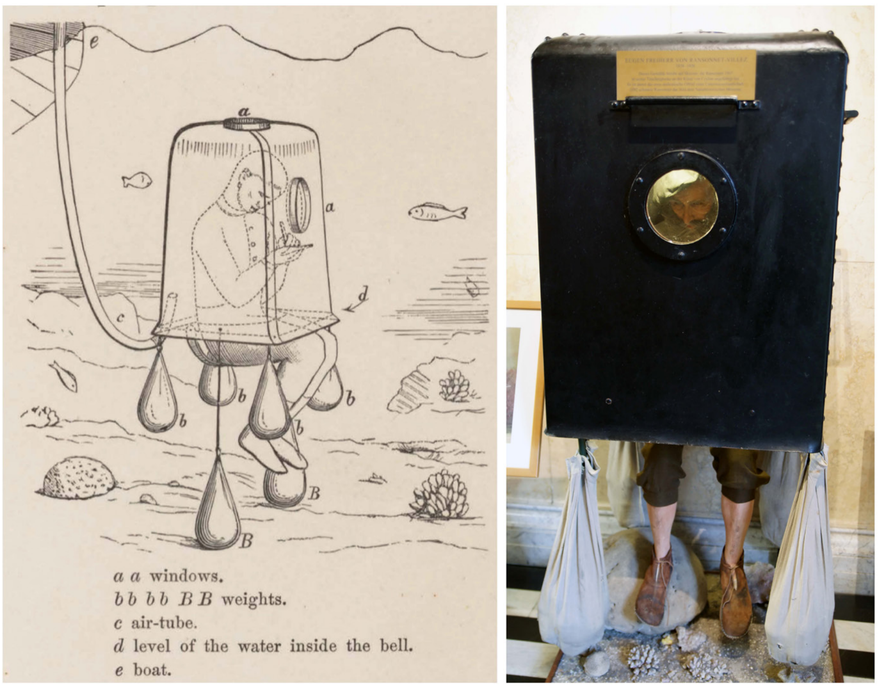

Figure 1. Diving bell constructed by Eugen von Ransonnet and used in the Red Sea and tropical Asia. Left: Sketch from Ransonnet (1867) showing the diving bell. The diver could move forward in any direction by simply raising the weights *BB* (textile bags with cannon balls), while the boat with the air-pump followed in his wake. Right: a model of the diving bell exhibited in the Natural History Museum, Wien (License under https://commons.wikimedia.org/wiki/File:Taucherglocke_von_Eugen_von_Ransonnet-Villez,_Naturhistorisches_Museum_Wien.jpg#globalusage).

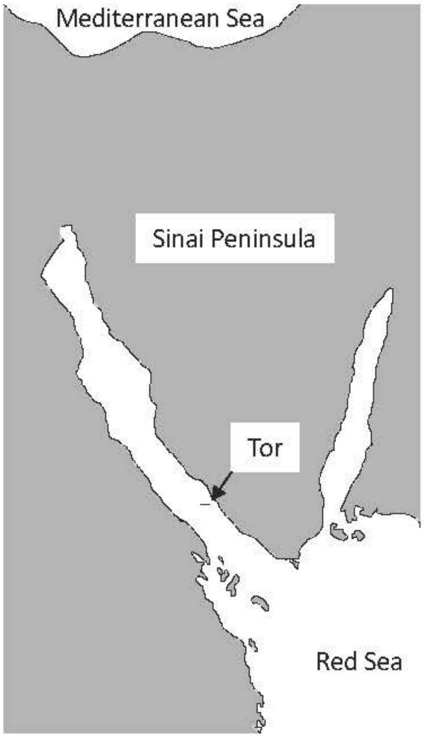

Figure 2. Location of the coral reef at El Tor, Egypt (28°13′32.67″N; 33°37′20.55″E).

DISCUSSION

The observations by Ransonnet and Haeckel show that coral bleaching was a phenomenon that occurred also during the cold period called the little ice age (*ca.* 1300 – *ca.* 1900). Its coldest period was during the 1600's. Since then, the global temperature has increased until today (Charpentier Ljungqvist 2017). The northern Red Sea is a marginal tropical area at a fairly high latitude. Systematic measurements of water temperatures do not exist for the Red Sea before 1900 and no oceanographic expeditions were sent to it at that time. Palaeoclimatological series covering the 1800's do not yet exist for the northern Red Sea. However, the reconstruction of the global palaeotemperature (Morice *et al.* 2012) shows that the year 1862, when Ransonnet made the observation on the coral reef, was exceptional. It was the absolutely coldest year since the beginning of their reconstruction in 1850 and probably even earlier during that century (Charpentier Ljungqvist 2017). The global temperature plummeted abruptly from a general temperature by about 0.35°C during that year (Morice *et al.* 2012), compared to the previous as well as the following years when Haeckel visited the same reef (Fig. 5). Such temperature changes must have affected symbiont-bearing corals in a similar way as they do today and resulted in the coral bleaching in 1862.

Numerous hermatypic coral species occur in a wide geographical area that extends over much of the tropical Indo-Pacific region (Hylleberg and Cedhagen 2015; 2018; Veron 2000) where the temperature ranges from *ca.* 20 to above 28 °C (Tchernia 1980; Tomczak and Godfrey 2002). During climate change, the temperature does not change uniformly everywhere on earth. As a rule, a heating or a cooling event is greatest towards higher latitudes and least around the equator (Charpentier Ljungqvist 2017; Ridd 2017). This pattern coincides with the pattern of coral bleaching caused by thermal stress. Such coral bleaching during the last decades is reported particularly from marginal lower-temperature areas of the entire distribution area of hermatypic corals (Goreau and Hayes 1994; Oliver *et al.* 2009; Burke *et al.* 2011). On the other hand it is generally not, or to a much lower extent, reported from the central area, the so-called Coral Triangle (Oliver *et al.* 2009; Burke *et al.* 2011; Ridd 2017), where the water temperature is around 2–8 °C higher and more stable than in the marginal areas (Tchernia 1980; Tomczak and Godfrey 2002).

Using presently available molecular techniques, it would be possible to investigate the genetics of coral symbionts from the Little Ice Age and compare with recent species in order to clarify their temperature tolerances. Numerous coral specimens collected during the Little Ice Age exist in museum collections. Ancient DNA of *Symbiodinium* species and varieties could probably be extracted, for example deep in the center of the calice, and sequenced from such material in order to clarify the phenomenon.

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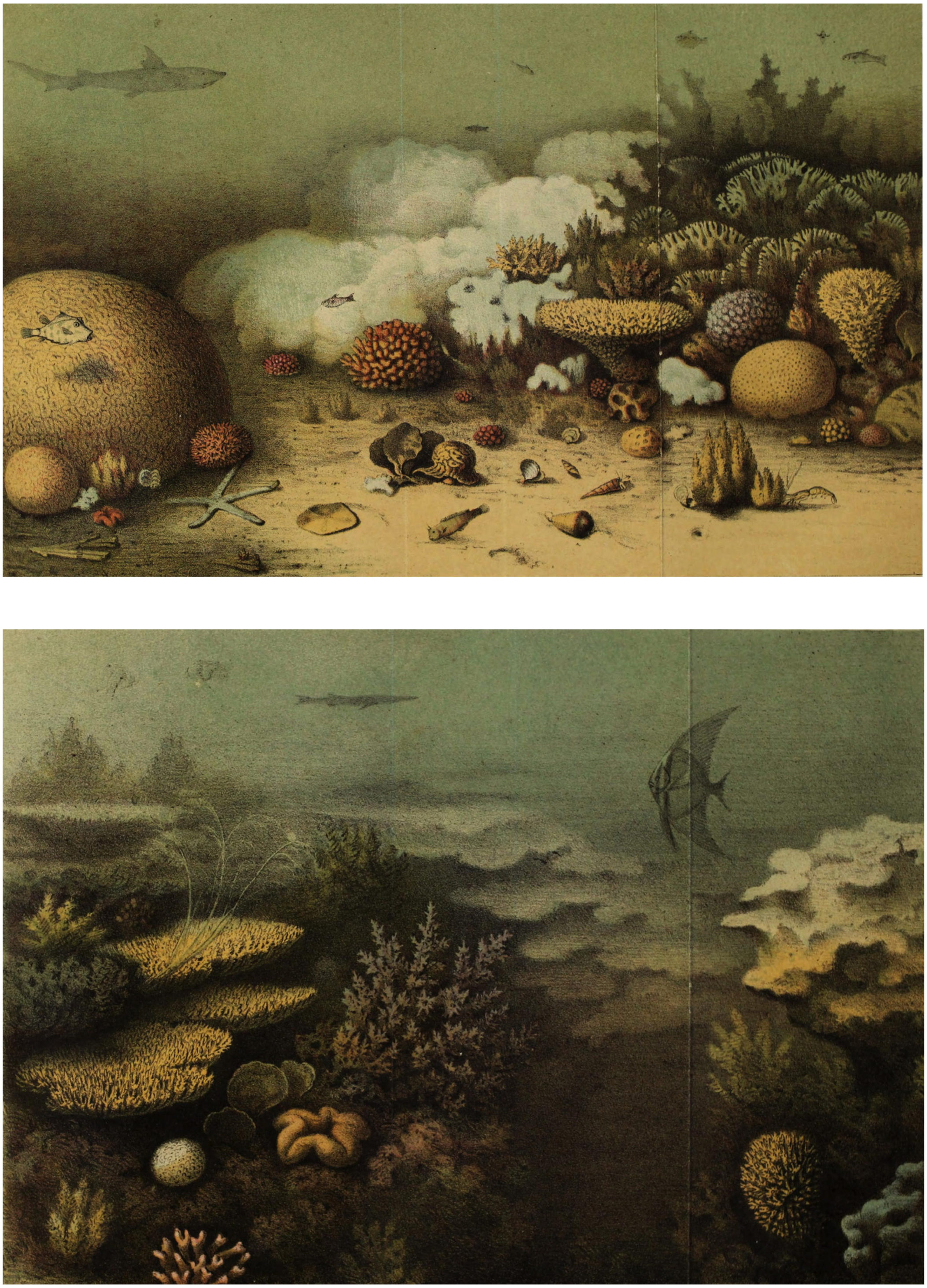

Figure 3. Reproduction of the colour lithographs by Ransonnet (1863) showing coral bleaching during his visit in 1862.

Figure 4. Reproduction of the colour lithograph by Haeckel (1876) without any signs of coral bleaching during his visit in 1873.

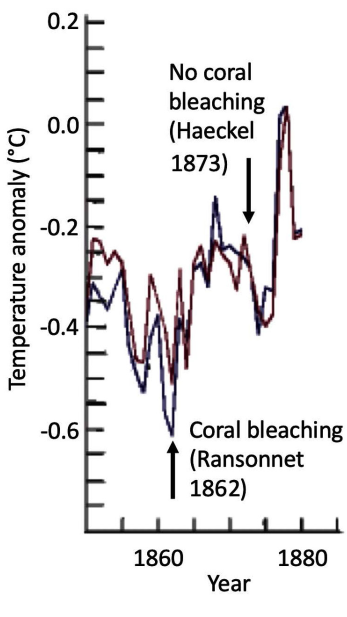

Figure 5. The global temperature from 1850 to 1880. Redrawn from Morice *et al*. (2012). The temperature anomaly refers to the period 1961–1990. Red: HadCRUT4 data series. Blue: HadCRUT2 data series. Field studies by Ransonnet (1863) and Haeckel (1876) are indicated for 1862 and 1873, respectively.

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