

Silent killer: black reefs in the Phoenix Islands Protected Area

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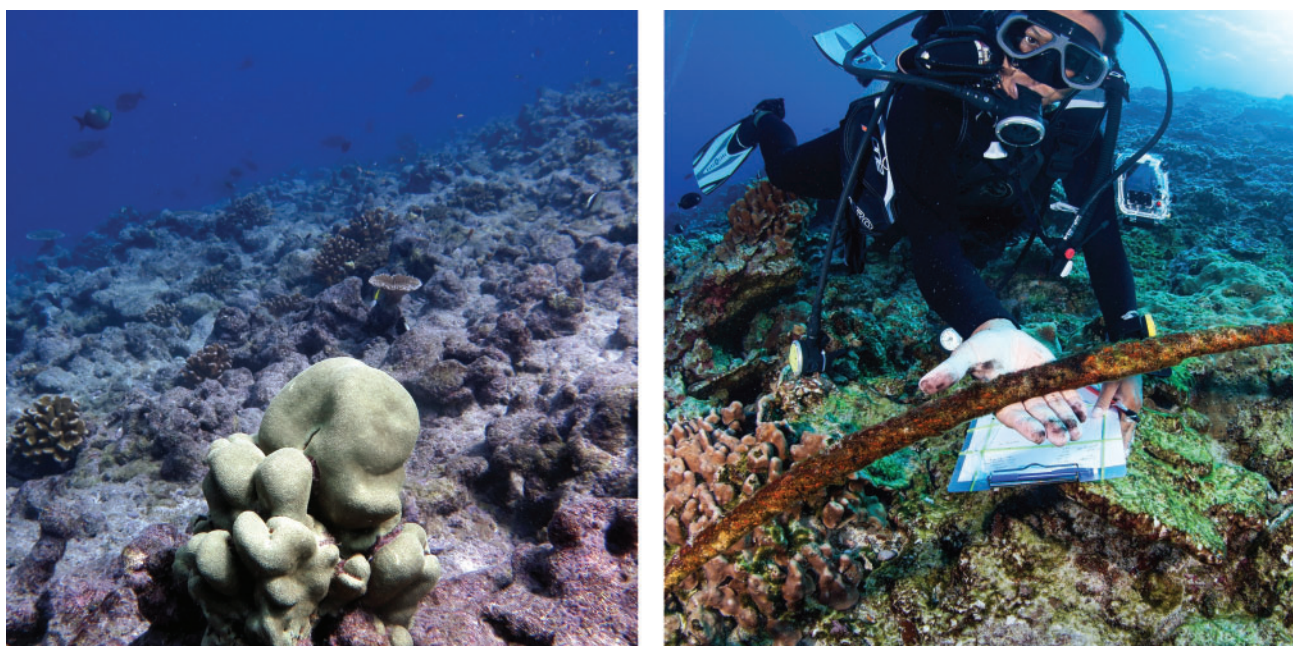


Fig. 1. Black reef at Nikumaroro Atoll (left, photograph by David Obura), and metal anchor line causing black reef at Carondelet Seamount (right, photograph by Craig Cook).

The Phoenix Islands Protected Area (PIPA) is in a naturally iron-poor region in the equatorial central Pacific. The main introduction of iron to this environment is from maritime debris, especially shipwrecks and anchor gear, and is linked to proliferation of turf algae and benthic bacterial communities, and the formation of degraded ‘black reefs’ (Schroeder *et al.* 2008; Kelly *et al.* 2012). Early surveys of coral reefs in the PIPA in 2000 and 2002 found near-pristine conditions at most locations, with a small number of degraded reef sites on three of the eight atolls, but with unknown attribution (Obura *et al.* 2011). After 2003, following mass coral bleaching associated with severe thermal stress (Obura and Mangubhai 2011), and with new evidence from the nearby Line Islands (Kelly *et al.* 2012), it appears that degraded black reefs in the PIPA can be attributed to iron contamination.

Black reef sites in the PIPA were characterised by low-percentage coral cover (4.9 ± 1.0) and high-percentage cover (79.8 ± 8.2) of cyanobacterial mats and turf algae in 2015, always associated with shipwreck debris (Fig. 1). While most shipwreck debris is relatively old (>50 years), monitoring from

2000 to 2015 documented the black reef originating at the 1929 wreck of the SS *Norwich City* on Nikumaroro Atoll in 2005, progressing northward to sites 1 km away, with low coral recruitment (0.22 ± 0.14 recruits per m^2). While fish diversity was notably lower at these reefs, dense schools of parrotfish and surgeonfish were observed feeding on the algae on multiple atolls (authors’ pers. obs.). The 2015 expedition to the PIPA recorded the presence of black reefs on five atolls (Enderbury, Kanton, Nikumaroro, McKean, Rawaki) and on Carondelet Seamount associated with shipwreck debris (Fig. 1). No recovery has been documented at black reefs observed between 2005 and 2015. Of concern is the 2009 shipwreck on McKean Island, creating black reef conditions along some 0.5 km of reef front and to 15 m depth, with low-percentage coral cover (3.3 ± 1.8) and high-percentage cover of cyanobacteria (56.7 ± 2.4) and turf (43.8 ± 15.8). Shipwrecks and the proliferation of turf and cyanobacteria can have impacts over more than a decade (this study; Schroeder *et al.* 2008). The removal of shipwreck debris from the PIPA is critical to address the spread of black reefs in this remote World Heritage Area.

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Conflicts of interest

The authors declare no conflicts of interest

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