Environmental science

Germ theory for ailing corals

Stephen R. Palumbi

Human activities damage coral reef ecosystems. Application of the 'germ theory', proposed more than a century ago for human diseases, could foster action on global environmental ailments such as this.

In 1876, Robert Koch was struggling to convince the world that germs cause disease. Today, environmental degradation is a pervasive planetary disease, but the causes remain shrouded in the same popular murk that made diseases mysterious before the work of Koch and Louis Pasteur. For environmental issues, such as the decline of coral reefs, sceptics demand detailed evidence — we must know the exact cause and show that any proposed cures will work. This is a tall order. Writing in *Science*, however, Pandolfi *et al.*[1] chart the decline of reefs using data from previous work[2] and some new evidence, and provide a prescription to begin a planet-wide cure.

Some demand that we rigorously prove the cause before acting. Koch faced this dilemma in the form of scepticism about the germ theory of disease. He responded by deploying the following postulates[3] for showing that particular bacteria cause a disease:

- The bacteria must be present in every case of the disease.
- The bacteria must be isolated from the host with the disease and grown in pure culture.
- The specific disease must be reproduced when a pure culture of the bacteria is inoculated into a healthy, susceptible host.
- The bacteria must be recoverable from the experimentally infected host.

These postulates do not always apply, even in medicine[3], but they emphasize the critical role of correlational[1,4] and experimental data[2,3] in untangling complex problems. These approaches are nearly ubiquitous in the environmental sciences and an environmental version of these rules might be termed 'planetary postulates':

- The cause must be present in every case of the environmental condition.
- The cause must be isolated and known to act by itself to harm the ecosystem.

_ The specific condition must be reproduced when the cause is experimentally introduced into the environment.

_ The cause must again be verifiably present and active in the affected environment.

Action to address serious environmental issues need not wait until all of these postulates are fulfilled. However, Pandolfi *et al.* meet most of them by showing that reef degradation is a disease of human overuse,as opposed to part of natural cycles. First, fully degraded reefs are always affected by people, because reefs with easier access or longer habitation are more likely to be degraded[1]. Second, some human activities harm reefs (Fig.1) — dynamite fishing,dumping sewage or sediment, dredging corals for cement and unsustainable fishing are well documented[4]. When people are excluded from reefs, fish and invertebrates tend to recover and reef decline tends to reverse[5].Third, when people are reintroduced to reefs — usually through the collapse of marine reserve enforcement — the condition of over-exploitation returns[6]. Fourth, once people return to reefs, they can be demonstrably shown to be harming them again[7].

Although the planetary postulates may be met for coral reef damage, human impacts are complex. The culprit may be sedimentation from terrestrial runoff[8] , excessive nutrient input from sewage[9], the introduction of foreign species or disease-causing organisms[10], overfishing[2] or global warming[11].

Analysing any one of these causes in isolation would not survive the strictures of the planetary postulates. But combining all of them, and their ultimate — human — driver seems to fulfil the postulates.

The value of this exercise should be that

Figure 1 **Net effect — one manifestation of deleterious human impact on coral reefs.Abandoned nets trap fish and diving birds, and abrade the coral.**

MASA USHIODA/IMAGE QUEST

diagnosis paves the way for a solution. Pandolfi *et al.* do not know exactly how to cure coral reefs of human overexploitation — no more than Koch, labouring in advance of the discovery of antibiotics, knew how to cure tuberculosis. Instead, they treat the problem as Koch might have done: keep the patients alive by alleviating the symptoms, and reduce exposure to the problem so that they can cure themselves.

To alleviate the symptoms, the most severe impacts on reefs must be reduced.

This may mean investment in sewage treatment and abatement of run-off from land; reducing fishing intensity; establishing fully protected reserves; or building buffer zones with limited development near reefs. In the long term it may mean reducing global warming. In the meantime, to keep the patient alive, it is necessary to establish large coral reef parks, such as the Great Barrier ReefMarine Park, as well as small reserves to act as local seed sources.

Finally, the patient needs to heal.Here the sea is ready to help. Marine species have prodigious reproductive abilities — many female fish and invertebrates produce millions of eggs a year. Some corals are virtually immortal and can fragment to produce hundreds of clonal offspring.Movement of tiny larvae can transport species from healthy to damaged reefs. Reefs have recovered from hurricanes, floods, tsunamis and volcanoes. They can also recover from us.

Critics will say that Pandolfi and colleagues'proposed solutions are not socially or technically feasible.Koch faced similar problems. The requirements of his postulates outstripped the abilities of the microbiology and medicine of his day. But Koch did not worry that he could not culture every disease organism, nor that disease germs could not necessarily be killed once identified.Then,as now, progress is attained in steps, and the identification of causes is a key step.

Pandolfi *et al*. make a final plea — don't demand a perfect solution.As an initial goal, it is enough that the health of a reef stops declining and begins to improve. The next step is urgently to develop the science of global ecology to provide a toolbox of more lasting solutions.

Stephen R. Palumbi is in the Department of Biological Sciences, Hopkins Marine Station, Stanford University, Pacific Grove, California 93950, USA.
e-mail: spalumbi@stanford.edu

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