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Prepared in cooperation with the Mote Marine Laboratory *Protect Our Reefs* program

Phage Therapy for Florida Corals?

Introduction

Coral disease is a major cause of reef decline and a significant problem in the Florida Keys (fig. 1). Of the many diseases and syndromes that have been described, very few so far have been linked to a specific pathogen (disease-causing organism). In all but one of those cases, the pathogen is a bacterium as shown in table 1.

Figure 1. A star coral (*Montastraea annularis*) affected by white plague type II, a disease caused by the bacterium *Aurantimonas coralicida*. (Photograph by Ginger Garrison, USGS.)

Much effort and money are being directed toward cataloging coral diseases, mapping locations of coral diseases, determining causes of coral diseases, and measuring rates of coral demise. Very little research is being directed at ways to prevent or stop coral diseases.

Table 1. Coral diseases and the microorganisms that cause them.

Disease	Pathogen	Type
Aspergillosis	*Aspergillus sydowii*	Fungi
Black band	Mixture of cyanobacteria and sulfur-cycling bacteria	Bacteria
Bacterial bleaching	*Vibrio shiloi*	Bacterium
	Vibrio coralliilyticus	Bacterium
White plague type II	*Aurantimonas coralicida*	Bacterium
White pox	*Serratia marcescens*	Bacterium

A grant from the Mote Marine Laboratory *Protect Our Reefs* program is allowing the U.S. Geological Survey (fig. 2) to conduct a preliminary study that will look at applying phage therapy to diseased corals in the Florida Keys.

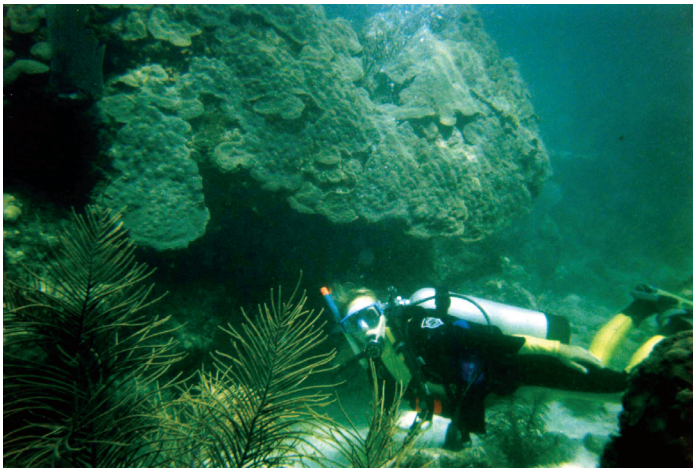

Figure 2. U.S. Geological Survey microbiologist Christina Kellogg near a large colony of healthy star coral in the Florida Keys. (Photograph by Peter Richardson.)

What is Phage Therapy?

The term "phage" is a shortened version of the word "bacteriophage," which literally means "bacteria eater." Bacteriophages are viruses that only infect bacteria (fig. 3). Phages are typically very specific, with each phage only able to recognize and infect a single bacterial strain. Phage therapy is the use of these bacteriophages as biocontrol agents to treat bacterial infections. Phage therapy was first developed in the 1930s to treat human bacterial infections, but the discovery of antibiotics made it obsolete in the Western world. However, the Soviet Union continued to study and test phage therapy and successfully used this treatment against agricultural pests, to treat livestock, and even in humans, both topically and internally. With the increase in antibiotic resistance, interest in phage therapy has been renewed. The U.S. Food and Drug Administration recently approved the use of phage therapy to treat packaged meat in an effort to eliminate potential food-poisoning bacteria like *Salmonella*.

Several factors about phage therapy make it a promising treatment option for coral diseases:

- Environmental safety—These bacteriophages already occur naturally in the marine environment, so their use does not introduce any foreign substances to the system.
- Specificity—As mentioned above, most bacteriophages are specific to one strain or species of bacterium, so treating a coral with one or more bacteriophages will only affect the target (for example, the bacteria causing the disease). In contrast, using antibiotics (which are non-specific) would affect all of the bacteria on a coral (both the disease-causing bacteria and the good bacteria) as well as the coral animal, the zooxanthellae, bacteria in the surrounding seawater and sediment, and other nearby marine organisms.
- Self limiting—Because bacteriophages need the bacterial host to reproduce, the virus particles will only persist as long as the bacteria being targeted are present; therefore, when the pathogen disappears, the viruses stop producing and eventually decay. This is another way that phage therapy is environmentally safe.

Hunting for Phages

A typical drop of seawater contains about 10 million viruses, most of them bacteriophages. Phage therapy involves trying to find very specific viruses that infect a particular coral pathogen. To accomplish this, large volumes of water (40-80 liters) are passed through a filtration system that allows the water molecules to pass through, but retains and recycles any particles, concentrating the virus community in the sample. After concentrating that community almost 100 times, the virus-containing samples are mixed with the target bacterium (coral pathogen) and incubated on nutrient agar plates. The bacteria will grow on the agar, and any viruses able to infect and kill the bacteria will appear as clear spots on the agar plate (areas where bacteria are not growing). These clear spots are then picked and purified, and the viruses they contain are characterized. Some examples of characterization methods include looking at the viral particles under a transmission electron microscope (TEM) to see their morphology (fig. 3), determining which type of nucleic acid (RNA or DNA) the particles contain, and using restriction enzymes to make nucleic acid finger prints to compare patterns between particles and to size the genomes.

Ongoing Research

The scope of the *Protect Our Reefs* project was to screen Florida reef environments for bacteriophages specific for coral diseases and then characterize these viruses. This work has been performed. Now researchers

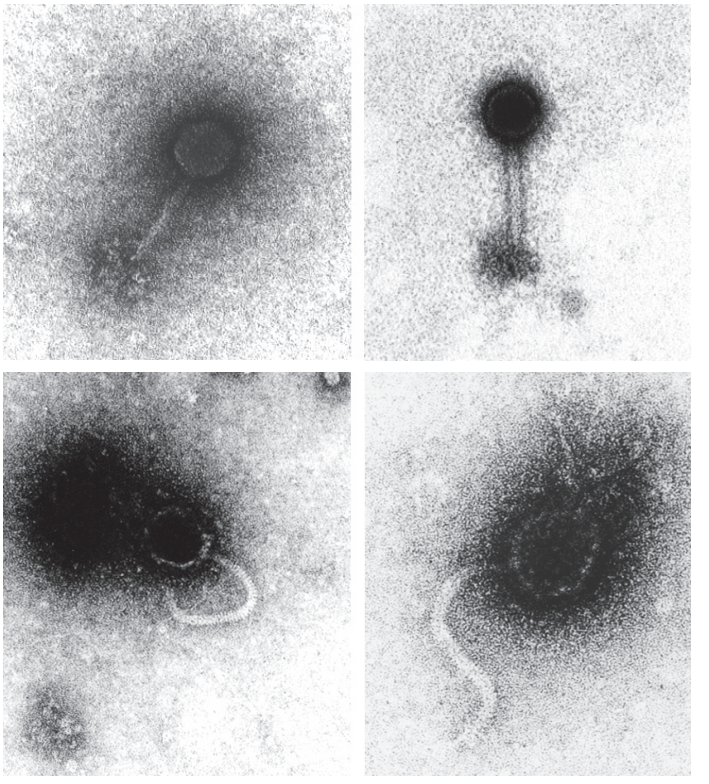

Figure 3. A transmission electron microscope (TEM) was used to take these images of bacteriophages. The top two images are phages that infect the bacterium *Aurantimonas coralicida* (cause of white plague type II disease) and the bottom two images are phages that infect the bacterium *Vibrio coralliilyticus* (cause of bacterial bleaching disease).

are preparing to move to the next phase of the study which involves testing the phage therapy treatment on diseased corals in aquarium experiments. A similar study was just conducted in the Red Sea using corals and bacteriophages native to that region, and the treatment was a success. As a result, prospects are good for using the bacteriophages characterized from Florida waters to treat diseased corals on the Florida reef tract–the only coral reef in the continental United States.

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Additional information about USGS coral microbial ecology research is available at:

http://coastal.er.usgs.gov/coral-microbes/