3.2 Bacterial Viruses in the Oceans
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Slide 1: Bacterial viruses in the oceans

The bacteriophages present in the oceans are by far the most abundant organisms there, with concentrations of intact particles as measured by epifluorescence microscopy exceeding their bacterial hosts by one to two orders of magnitude, at around 10^9-10^{10} virions per liter. If we were to count all of these marine phages we would find around 10^{30} total, for a sense of scale, this is a number close to the mass of the sun in pounds. Similarly, even though phage are only around 125 nm long, which is about a fifth as tall as the wavelength of visible light, if you were to stack them one on top of the other end to end you would get a spire that would be 10,000,000 light years tall. It would stretch out past the next galactic cluster. We are finding that these viral agents of bacterial death may be among the most dominant players impacting and modulating marine ecosystems, accounting for 10-30% and up to 72% of all bacterial mortality in aquatic systems.

Slide 2: The viral shunt

All of this bacterial lysis involves the release of large amounts of sequestered carbon and other nutrients into the environment as Dissolved Organic Matter (DOM) and Particulate Organic Matter (POM) through a process described as the viral shunt. These released cell contents can then be consumed by heterotrophic organisms specialized at living on non-cell associated organic matter. Additionally this process may drive much of the deposition of ancient carbon through the release of large quantities of recalcitrant organic matter, leading to long term carbon storage in the oceans and the 'marine snow' phenomenon.

Slide 3: Influence on climate

However, while the viral shunt appears to shift large amounts of carbon annually from marine bacteria into both labile and recalcitrant pools, it also appears to have a profound effect on the efficiency of bacterially mediated carbon fixation. Indeed, the Scanlan and Millard groups at the University of Warwick have found that phage infected populations of cyanobacteria fix 4.8 and 2.3 times less carbon, respectively, than uninfected hosts. Indeed, while they found that phages appear to promote photosynthesis within infected cells, they then appear to use the energy produced to make phage particles rather than fix inorganic carbon into sugars. They estimate that this could prevent the fixation of calculations this engineered inefficiency would prevent the fixation of 0.2 to 5.5 gigatons of carbon every year, or 10% of the total produced by the oceans.

Slide 4: Kill the Winner (KtW) model

The large amount of selective pressure applied by all of this virally induced bacterial mortality also forms the basis for the Kill the Winner model, which can be used to explain why the molecular diversity of the oceans is enormous even though the challenging and stable conditions would seem as if they should select for a dominant and particularly well adapted species. Indeed, what prevents the most competitive bacteria from globally out competing other strains? According to this model bacterial populations present in the oceans become more vulnerable to phage predation in dense concentrations of clonally related blooms, as bacterial success will naturally lead to the greater success of viral predators capable of infecting them. While there is clear evidence that in some contexts viruses do indeed ‘kill the winner’ in the case of some bloom forming species, there are also clear instances in which blooms persist in the presence of infectious viruses. This suggests that a better understanding of host-virus interactions on both a molecular and ecological level may lead to a much deeper understanding of environmentally and economically harmful blooms.

Slide 5: Applications of marine viruses

More specifically, the application of phage therapy to diseased corals afflicted with white plague-like and other diseases has been attempted with apparent success in the Red Sea off Aqaba and in the Great Barrier Reef off Australia. Indeed, Atad et al. (2012) have found that the application of their phage BA3 can inhibit the progression of white plague-like disease in *Favia favus* coral and that treated corals will only infect 5% of nearby healthy corals rather than the 61% infected by no-phage controls. Similarly, Cohen et al. (2013) have isolated a phage infecting *Vibrio coralliilyticus, a* pathogen that causes paling due to loss of an animal symbiont, which is capable of rescuing the animal symbiont in vitro.