Is Your Sunscreen Stressing Out Coral Reefs?

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Writer's Comment: *One topic Professor Katie Roger talked about extensively in my UWP 104E class was the importance of being able to communicate scientific information to a non-specific audience. We discussed how terminology and styles of writing become specialized in different areas of academia, which limits the audience of a scientific article, and, unfortunately, limits the extent to which information is spread. If we do not understand something, why should we care about it? For an assignment in my scientific writing class, I decided to research the relationship between coral bleaching and the ingredients in sunscreen, and I synthesized this information for a general audience—UCD students. While there are many factors that contribute to coral bleaching, I hope readers will consider how small changes they make in their lives can help save fragile ecosystems like coral reefs. A huge thank you to Professor Katie Roger for her guidance and encouragement as I developed my abilities as a writer.*

Instructor's Comment: *Students studying science at UC Davis are often eager to practice and hone their skills for writing scientific papers, as they recognize the importance of this kind of writing in their respective fields. So the bulk of my UWP 104E course focuses on technical forms and techniques. At the end of the quarter, however, we turn to "popular" science writing—or writing for a non-specialized audience. Often students question the need for this kind of writing, as they doubt the necessity for it in their futures as scientists and technical professionals. Yet in each class, one or two students fully embraces the Feature Article assignment that asks them to write about a technical topic in a manner appropriate for a magazine or newspaper that would be read by a general audience. In my spring 2014 class, Mackenzie Nelson was one of those students. Immediately after we discussed the assignment in class, Mackenzie approached me with ideas for her article, knowing that she wanted write about the impact of chemicals in sunscreens on coral reefs. It's a great topic for this kind of writing, but I was blown away by Mackenzie's final essay. Her tone and organization of information is* *excellent and her piece could easily be found in a nature or health magazine. I am thrilled that Mackenzie's piece was selected for this year's* Prized Writing, *and I look forward to seeing what she does next.*

—Katie Rodger, University Writing Program

It's the end of the quarter. You turn in your last final and head straight home to catch up on all the sleep you've missed out on for the past week. A few hours later, you wake up and—BAM—you are coughing, sneezing, and running a fever. Most of us students are familiar with this post-exam sickness and the way it unleashes its wrath when we would rather be celebrating at the bar downtown with our friends.

We stress when we study for exams, and when we're stressed, our immune systems are weakened—making us more susceptible to infection from the many viruses that surround us on a daily basis, like the common cold (Maddock & Pariante, 2001; Jemmott & Mgliore, 1988). Corals experience a similar phenomenon.

When coral animals and their symbiotic organisms—organisms that have an interdependent relationship with coral—are stressed, they are more likely to contract a viral infection from the natural population of viruses that exist in the 4 cm of water surrounding them (Donovaro et al., 2008; Than, 2008). These viral infections result in a fatal event for coral reefs called coral bleaching (Donovaro et al., 2008).

What stresses corals? A number of factors, actually, including nutrient enrichment, ocean acidification, land-based pollution, climate change, unsustainable fishing, and aquatic invasive species (Donovaro et al., 2008; Than, 2008; National Oceanic and Atmospheric Association, 2014). But one factor that receives the least amount of recognition is sunscreen contamination.

Yes, the topical sunscreen you slather on religiously before heading out for a day in the sun is killing coral reefs. More specifically, titanium dioxide, zinc oxide, and the paraben, cinnamate, benzophenone, and camphor derivatives found in popular sunscreens—like Coppertone and Neutrogena—are threatening ten percent of coral systems worldwide (Donovaro et al., 2008; Cousteau, 2012; Miller, Bennett, Keller, Pease, & Lenihan, 2012; Jovanovic & Guzman, 2014; Wong, Leung, Djurisic, Leung, 2009; Reed, Ladner, Higgins, Westerhoff, & Ranville, 2012).

What is coral bleaching?

Coral lives in a symbiotic relationship with colorful photosynthetic algae, called zooxanthellae. The zooxanthellae cells conduct photosynthesis, a metabolic process catalyzed by light, to convert carbon dioxide (CO_2) into oxygen (O_2) and sugars. These oxygen and sugar products are used by coral in respiration—a process in which animal cells create the energy needed to function—and produce carbon dioxide, which is then consumed by the zooxanthellae to once again go through photosynthesis.

Zooxanthellae contain pigments that absorb light and allow photosynthesis to occur. These pigments are what give color to the coral. So when the colorful zooxanthellae die or are expelled from coral, the white calcium carbonate skeleton of the coral is exposed, making it appear "bleached" (Donovaro et al., 2008; Lyons, 2008).

Why is sunscreen a culprit?

Each time we enter the water—whether it be a pool, a lake, or the ocean—around a quarter of the sunscreen we spent several minutes covering our bodies with gets washed off. Each year, approximately 4,000 to 6,000 metric tons of sunscreen gets washed off into the ocean (Donovaro et al., 2008; Than, 2008; Cousteau, 2012). The ingredients in sunscreens are lipophilic, meaning they do not dissolve in water. Therefore, this annual addition of sunscreen contamination progressively accumulates in our water system (Donovaro et al., 2008; Than, 2008; Cousteau, 2012).

Sunscreen components act as barriers that prevent the UV radiation emitted by the sun from penetrating our skin. Titanium dioxide and zinc oxide act as physical barriers that reflect UV radiation (Miller et al., 2012; Jovanovic & Guzman, 2014; Wong et al., 2009; Reed et al., 2012). The metal ions that eventually result from the breakdown of these molecules in the presence of light are detected in coral samples that experience bleaching due to oxidative stress—this occurs when the vital biological reactions involving oxygen in coral and zooxanthellae, photosynthesis and respiration, are disrupted.

Paraben, cinnamate, benzophenone, and camphor derivatives prevent UV radiation from penetrating the skin by absorbing the radiant energy and triggering a photodegradation reaction—the break-down of molecules in the presence of light (Gallardo et al., 2010). An unfortunate product of this type of reaction is a free radical isomer, a molecule with an unpaired electron that is very unstable (Gallardo et al., 2010). To become stable, free radicals steal electrons from other components within the cells of coral or zooxanthellae to create another unstable free radical (Donovaro et al., 2008; Gallardo et al., 2010). This chain of free radical reactions disrupts natural processes within zooxanthellae and coral, like photosynthesis and respiration (Gallardo et al., 2010). Without these two processes, the stressed zooxanthellae and the coral become weak and more susceptible to viral infections.

Stress is Making Coral Reefs Sick

There is a natural population of viruses that exists around coral reefs—similar to how we are surrounded by viruses in our daily lives (Correa, Welsh, & Thurber 2012; Marhaver, Edwards, & Rohwer, 2008). Because zooxanthellae and coral are stressed and their normal metabolic functions are not working properly, their immune systems are not strong enough to fight off infections (Donovaro et al., 2008; Than, 2008; Marhaver et al., 2008). The viral population grows dramatically, as is evidenced in studies that found a factor of fifteen increase in the concentration of viruses in the water surrounding coral during a bleaching event (Donovaro et al., 2008; Davy et al., 2006). When the viruses have proliferated to the point that the coral or zooxanthellae cells die, the viruses move on to infect other coral reef organisms (Donovaro et al., 2008; Than, 2008; Reed et al., 2012).

If you are afraid of catching one of these coral viruses, don't be. While they do resemble some human viruses, the viruses that infect corals and their symbionts are species-specific. A herpes-like virus (HLV) is now known to cause infection in the coral animal, making up 4-8% of the virus population—an increase of 6 orders of magnitude in infected coral samples compared to healthy samples (Marhaver et al., 2008; Thurber et al., 2008). The viruses specific to the zooxanthellae include dsDNA nucleocytoplasmic large DNA virus (NCDLV) and +ssRNA dinornavirus (Correa et al., 2012). As these viruses continue to grow in population, they disrupt the symbiotic biological processes in the coral and zooxanthellae, leading to coral bleaching.

How true is this?

There have been arguments from researchers that sunscreen has little effect on coral bleaching compared to other factors. According to Robert van Woesik, a coral expert at the Florida Institute of Technology (as cited in Than, 2008), "Under normal situations on a coral reef, corals would not be subjected to these high concentrations because of rapid dilution." The concentrations van Woesik is referring to include 10, 33, 50, and 100 μL of sunscreen per liter of water—concentrations tested by Donovaro et al. (2008). In this experiment, coral bleaching occurred even at the lowest concentration, 10 μL/L, which is a dilution of 10,000-to-1 volumes of seawater to sunscreen.

The ocean contains around 11,106,070,554,493,600,000 metric tons of water, which means that an annual addition of 4,000 to 6,000 metric tons (estimate by Donovaro et al.)—since sunscreens became popular in the 1950s—would be diluted about 50,000,000,000,000-to-1 volumes of seawater to volumes of sunscreen in the last sixty years. This is a dilution that is over a factor of nine times greater than what was tested by Donovaro et al.

However, sunscreen volumes are not added uniformly throughout the entire ocean. Instead, these volumes are most likely concentrated to coastal areas and, more specifically, to areas closer to the equator—where climates are warmer because of more intense solar radiation, warmer climates, and more tourist attraction. Therefore, these 4,000 to 6,000 metric tons of sunscreen are being added to specific parts of the world, effectively increasing the concentration of sunscreen in those areas.

While sunscreen may not have as much impact on coral bleaching events as rapidly increasing ocean temperatures, any way to mitigate human-caused impacts on coral reefs can only benefit reef health.

Why should we care about coral reefs?

Aside from the fact that coral reefs are beautiful and complex structures, they are also important ecological and economical resources. Around the world, 500 million people depend on coral reefs, which provide an annual contribution to global economies of $29.8 billion (National Oceanic and Atmospheric Association, 2014). Coral reefs provide food and profit local fisheries, create a diverse habitat for marine organisms to breed, protect shorelines from storms that cause coastal erosion, attract tourists and recreational aquatic sports enthusiasts, and even contribute to medical breakthroughs (National Oceanic and Atmospheric Association, 2014; Crisley, 2014).

Is there a way to fix this?

Certain species of coral have shown to be resistant to coral bleaching. Scientists are considering the possibility of harvesting these more resistant corals and transplanting them into areas that have shown the greatest rates in coral bleaching. Marine biologist Steve Palumbi, of Stanford University, is leading a team of researchers in farming resistant corals (Mascarelli, 2014). They are looking at different species of coral and how they flourish or decline under certain conditions. For instance, the coral species *Acropora hyacinths* are being observed in two different locations: one in an area that experiences extreme fluctuations in temperature daily, changes around 6°C, and another in an area that experiences relatively consistent temperatures (Mascarelli, 2014). When placed in tanks and exposed to high temperatures for several days, the coral samples from the location with greater temperature fluctuations bleached later than the coral samples from the less variant location (Mascarelli, 2014).

What can we do?

The best thing any consumer can do is to get to know the product being purchased. Avoid sunscreens with ingredients related to parabens, cinnamates, benzophenones, or camphors or that have the active ingredients titanium dioxide and zinc oxide. This means you need to do your homework. Look at the ingredients in your favorite sunscreen products and search for descriptions of them on the Internet. Find out how they may impact the environment.

Then, look for alternative products. There are a variety of topical sunscreen options with ingredients that do not harm important environmental ecosystems, like coral reefs.

The law of unintended consequences acknowledges that unanticipated outcomes may result from some sort of intervention in a complex system—in this case, sunscreen interrupting natural coral reef processes. If you could make even just one small change, as simple as altering your sun-protection methods, to help alleviate that consequence, would you?

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