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Does oxybenzone affect the development of sea urchins up to the gastrula stage, and what do we do about it?

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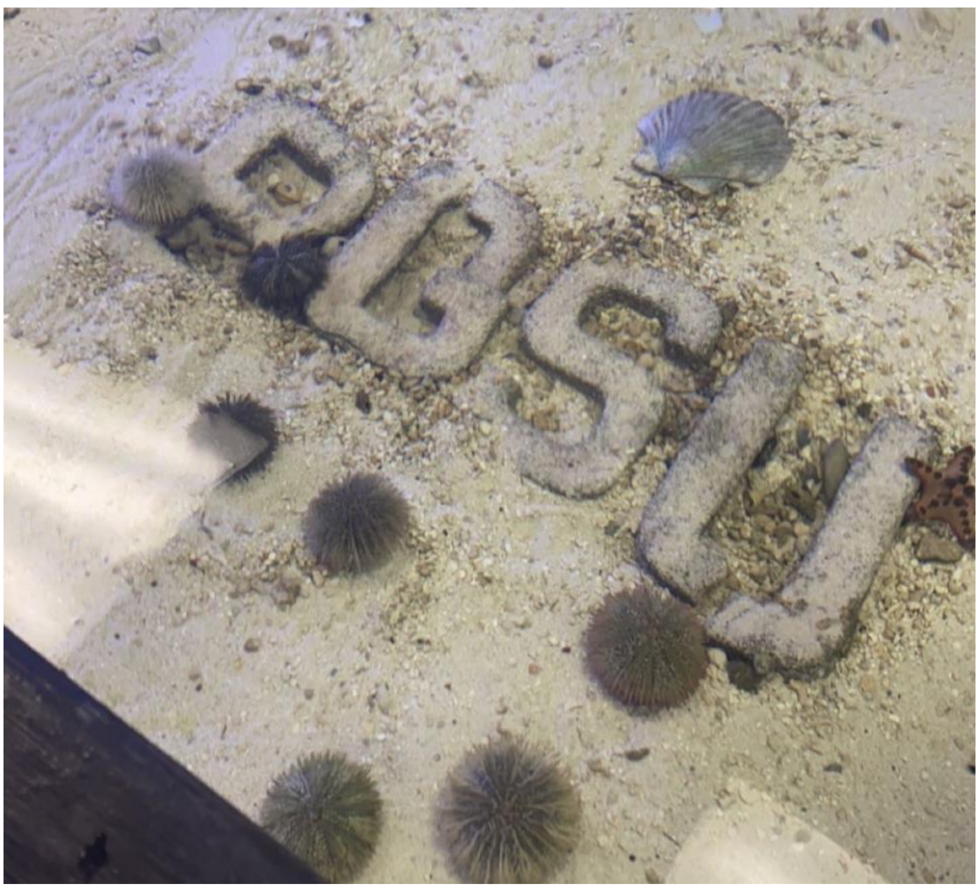

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INTRODUCTION

It is well known that coral reefs are of environmental concern due to climate change. Coral reefs are struggling to recover from bleaching particularly due to the rate at which ocean warming events are occurring (Hughes et al., 2018). In order to make the most of the brief recovery period corals do have, factors other than water temperature must be understood and maintained if possible. One such factor is the presence of herbivores on coral reefs (Williams, 2022). Herbivores maintain a balance between algae and corals. Algae have negative impact on the regrowth of corals (Adam et al., 2015). Herbivorous organisms, such as fish and sea urchins, help keep algal growth under control through grazing. Many reef fish are overfished, further lowering the recovery of corals. However, many fisheries rely on herbivorous reef fish, meaning that complete bans on fishing these important organisms are not feasible (Adams et al., 2015). As overfishing continues to rise, the herbivore role begins to fall more on the less fished sea urchin populations. In fact, sea urchins are one of the only impactful coral reef herbivores that are not experiencing population decline due to overfishing. A strong positive correlation between the presence of sea urchins and juvenile corals has been observed on coral reefs in Taiwan (Dang et al., 2020). Juvenile corals indicate the regrowth of damaged or bleached coral reefs. Not only are sea urchins ecologically important, but they also serve as an excellent model organism due to their availability, the biology of embryos, and their easily induced reproduction (Ettensohn 2017).

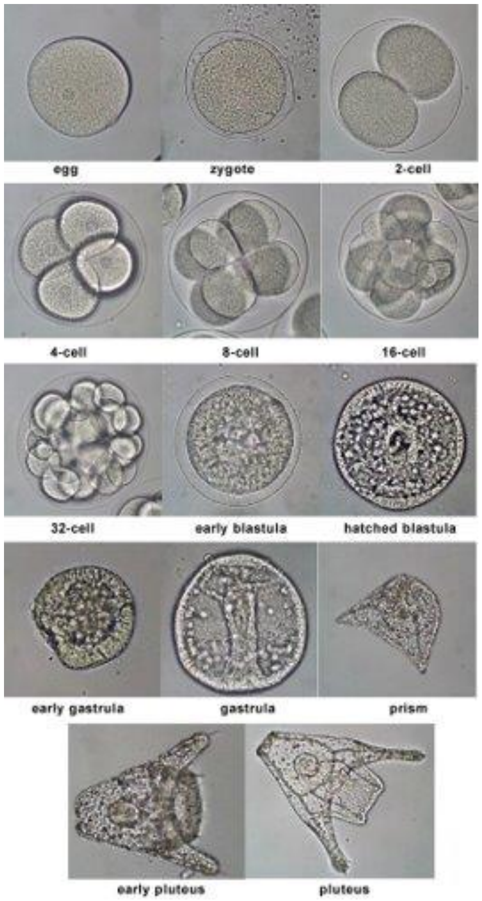
Although the importance of herbivores, specifically sea urchins, is well researched, there is a gap of knowledge in how anthropogenic factors affect them. One such factor is oxybenzone (OXI), a chemical that is widely used in sunscreens and is known to negatively affect coral planulae (Downs et al, 2015) (Vuckovic et al., 2022). In order to best encourage coral recovery, the effects of this chemical must be understood in the herbivorous sea urchins. One study aimed at establishing a simple and reliable test for the toxicity of different contaminants on sea urchin embryos did preliminary tests of OXI's effect on sea urchin reproduction (Bošnjak et al., 2011). This study aims to answer the question does oxybenzone negatively affect development of *Lytechinus variegatus* up to the gastrula stage.

METHODS

Sea urchins, *Lytechinus variegatus*, ready for gamete release were purchased from Carolina Biological. One day after arrival they were injected with 0.1 mL of 0.5 M potassium chloride. The injection sites were on each side of the mouth of the urchin. They were placed on top of a sample cup full of seawater at which point they released their gametes. The eggs were collected with a pipette and added to petri dishes containing OXI contaminated sea water. Approximately 3 drops of the egg solution were added. Five drops of the sperm solution were diluted with 150 mL of seawater. One drop of the new sperm solution was added to the petri dishes.

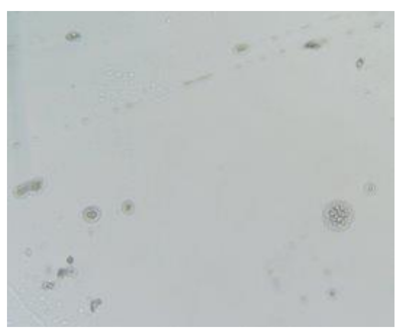
Each petri dish contained approximately 50 mL of water. The control group had no oxybenzone. The treatment dishes were 6,000, 2,000, and 667 ng/L contaminated sea water. These levels were decided based upon a survey of water located in the US Virgin Islands.

The petri dishes were placed on an orbital shaker that simulated the waves the developing urchins would naturally experience, as well as keeping the water oxygenated. After 24 hours 2 drops of the zygote solution were placed on a depression slide and viewed under an Olympus BH-2 light microscope to observe the blastula stage. The top layer of the water was drawn off with a pipette and replaced with new water. The same procedure was followed at 48 hours to observe the gastrula stage. The number of urchins that reached the stage and the number that were deformed were recorded. The following reference chart, obtained from Swarthmore Developmental Biology Lab, was used to identify properly developed embryos.

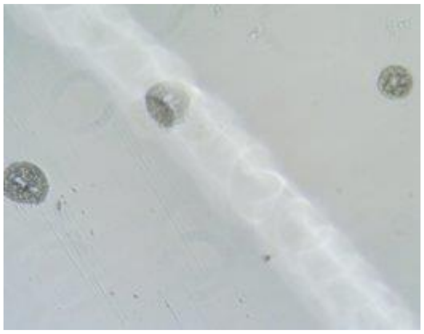
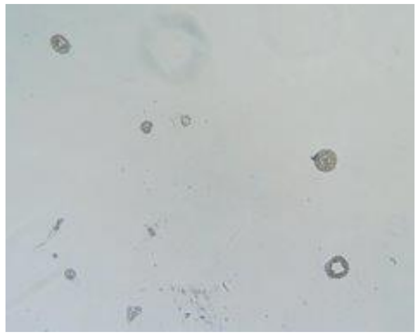


RESULTS

Control:



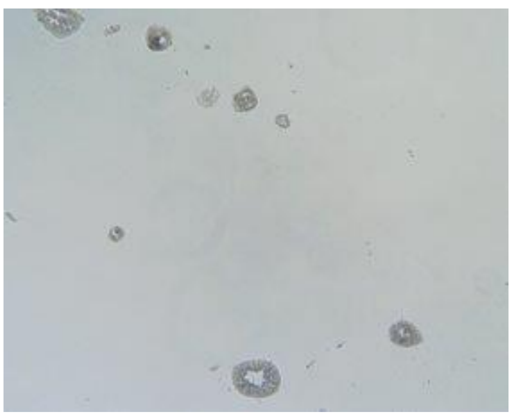
6,000 ng/L OXI:

2,000 ng/L OXI:

667 ng/L OXI:



Images showing the observed gastrula stage embryos under the Olympus BH-2 light microscope

Graph 1: Number of gastrula-stage embryos per treatment group

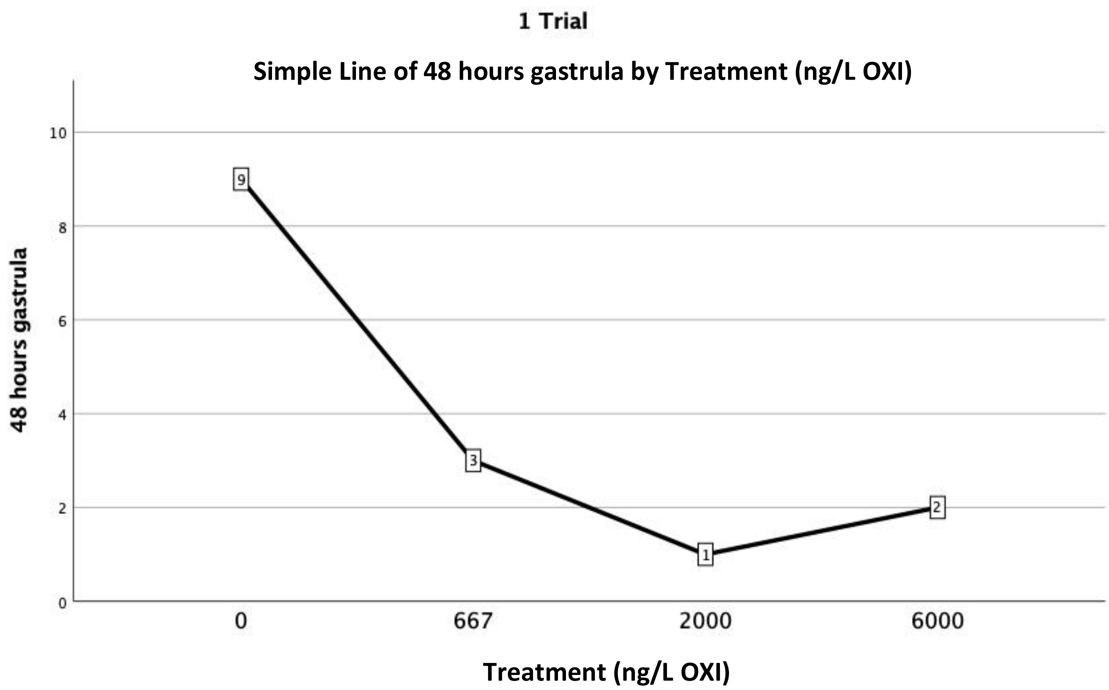


Table 1:

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The distribution of 48 hours gastrula is the same across categories of Treatment (ng/L OXI).	Independent-Samples Kruskal-Wallis Test	.000	Reject the null hypothesis.

a. The significance level is .050.

b. Asymptotic significance is displayed.

Table 2:

Pairwise Comparisons of Treatment (ng/L OXI)

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
2000-6000	-20.000	7.116	-2.811	.005	.030
2000-667	40.000	7.116	5.621	.000	.000
2000-0	60.000	7.116	8.432	.000	.000
6000-667	20.000	7.116	2.811	.005	.030
6000-0	40.000	7.116	5.621	.000	.000
667-0	20.000	7.116	2.811	.005	.030

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .050.

a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

Graph one indicates the number of embryos that properly developed to the gastrula stage after 48 hours. Nine embryos in the control had developed to the gastrula stage. The 667 ng/L OXI treatment had 3 develop correctly, the 2,000 1, and the 6,000 2. A Kruskal-Wallis test was ran on this data to determine the significance. As shown in table one, the data is significant, and the null hypothesis was rejected, indicating a difference between treatments. Table two is the pairwise comparisons showing that there is a significant difference between each treatment.

DISCUSSION

Observations of the data indicate that oxybenzone negatively affects the development of *Lytechinus variegatus.* While the data was significant, there are limits to the study. This was a short term study, with only one trial due to time and budget restraints. A longer term study with multiple trials may provide a more comprehensive understanding of the effect of oxybenzone on sunscreen. Understanding the effects of anthropogenic factors, such as oxybenzone, on sea urchins is extremely important to protect the growth of coral reefs- the ocean's hotspot for biodiversity. Having scientific evidence on this matter helps influence laws regarding the chemicals allowed for use in topical sunscreens.

Using both my data and knowledge from standing literature, I decided to write a policy analysis paper to answer the question "what should we do regarding sunscreen pollution?" My literature research resulted in me choosing to look at the effect of oxybenzone and octinoxate, as those are the most harmful chemicals. Policy analyses aim to determine the best solution for a problem through qualitative methods. It can provide information as to what policies or methods should be used in reaction to a specific issue.

Policy Analysis

PROBLEM STATEMENT

Coral reefs are exceptionally important habitats – they house thousands of aquatic species, produce large amounts of oxygen, protect coastal communities, and contribute to global economies in more than one way (NOAA, 2013 & Maragos et al., 1996). About half of all US federally managed fisheries depend on coral reefs. The commercial value of these coral reefs to the US fisheries is estimated at over 100 million dollars (NOAA). Despite human reliance on coral reefs, anthropogenic factors are namely the cause of coral reef destruction.

The deterioration of coral reefs is a widespread issue. Virtually every reef across the globe is affected by anthropogenic factors, whether that be direct (sunscreen pollution or damage from fishing practices) or indirect (overall water warming or long reach pollution). Focusing on sunscreen pollution in the US, the most affected areas are largely tourist locations like Hawaii and Florida coastlines. Because coral reefs protect coastal communities from waves, storms, and floods, destruction can eventually displace the millions living in these communities (NOAA). Destruction of reefs also will affect the hundreds of thousands of people who rely on income from fisheries and tourism.

There are multiple causes of coral reef stress. Ocean warming events are occurring at increasingly close intervals, causing bleaching (Hughes et al., 2018). Food chain disruptions caused by overfishing lead to the crowding out of corals (Adam et al., 2015). Pollution, physical or chemical, also impacts the health of reefs. One source of pollution is sunscreen products used during recreational activities on or nearby reefs (Corinaldesi et al., 2018). While sunscreen is a rather small part of reef destruction, it is a very actionable issue. Unlike issues such as water warming and ocean acidification, this is a single faceted issue that can more easily be remedied.

POLICY ALTERNATIVES

My goal is to identify the best policy to combat coral reef stress caused, in part, by oxybenzone and octinoxate, which are two chemicals commonly found in sunscreen. To reach a policy recommendation, two policy alternatives will be evaluated on terms of effectiveness, efficiency, and political feasibility. Effectiveness, as described by Kraft and Furlong, is ‘the likelihood of achieving policy goals and objectives or demonstrated achievement of them.’

Efficiency is the success of the policy in relation to the cost in time and money. Political feasibility evaluates the likelihood of acceptance and support from political officials.

Regulating the term ‘reef-safe’ could be an effective solution to sunscreen pollution on coral reefs. Some companies label sunscreens that can be sold in Hawaii as reef safe, while others use it as a form of greenwashing. The term is not currently regulated, meaning it can be found on any sunscreen bottle, whether it is truly safe or not. Toxicity standards will also need to be formed to pool accurate information regarding the 16 FDA approved sun filters. From there, the relative hazard of each can be evaluated and compared to find the filters with the smallest impact on coral reefs. Those filters can then be used to create a standard for ‘reef-safe’ sunscreen.

This solution would allow consumers to make a choice that is in alignment with their intentions. Beach goers in Hawaii were surveyed before Hawaiian government banned the sale and distribution of sunscreen containing oxybenzone and octinoxate (Levine, 2020). The majority of respondents were willing to switch to a reef safe sunscreen, however their lack of knowledge about which sunscreens to buy obstructs them from doing so. Regulating the term would make choosing environmentally friendly products simple to the consumer. Even without any bans on ingredients the use of them would decrease as consumers can quickly make an informed decision on which product to purchase.

Banning the sale and distribution of the two chemicals that are generally considered to be harmful, oxybenzone and octinoxate, is another potential solution. Hawaii put a similar ban in place in 2021 on the sale and distribution of sunscreens that contain oxybenzone and octinoxate. This would certainly be the most direct way to prevent these chemicals from entering the oceans. The use of harmful sun filters at coral reef sites, during recreational activities like snorkeling, will dramatically decrease. While it may seem unnecessary to enact the ban in landlocked states, many people bring their own sunscreen with them as they travel to coastal states. Many people also practice daily use of sunscreen, even when not entering bodies of water. This eventually gets rinsed down drains and sent to waste water treatment plants, which are only somewhat successful at filtering the chemicals.

ASSESSING POLICY ALTERNATIVES

Table 3: Evaluative Criteria

	Efficiency Strengths	**Effectiveness Strengths**	**Political feasibility strengths**
Term regulation		- Encourages an environmentally friendly mindset in consumers	- Term regulation is feasible and has been done before in the FDA. - Social acceptability
Complete ban	- Relatively quick process	- Will eliminate the majority of oxybenzone and octinoxate use	- Can easily be done in states with sustainability as a value. - Social acceptability
	Efficiency Weaknesses	**Effectiveness Weaknesses**	**Political feasibility weaknesses**
Term regulation	- Testing protocols need to be done first. - Analysis and regulation will take time	- Will not directly change the use. - Not guaranteed that numbers go down.	
Complete ban		- Impossible to ban every chemical with an impact on reefs	- Bans like this are likely to be left to state or local governments. - Is more difficult to pass in some states than others

Term regulation is a politically feasible option, as it doesn't require the outright ban of any chemicals. It simply regulates what companies can label as 'reef-safe', such as the term 'organic' in the food industry. It is still considered to be an effective solution because it clarifies choices for the consumer. The previously mentioned survey shows consumers are willing to switch to reef safe sunscreens, however, they are unsure on what that means. Between standardization of chemical testing procedures, chemical testing and analysis, and term regulation this will likely take multiple years. It also does not prevent harmful sunscreens from being sold. This solution relies heavily on the consumer to make the decision to purchase reef safe sunscreen.

Enacting a complete ban is a more efficient solution, as a ban on chemicals containing oxybenzone and octinoxate can happen in less than a year. It also ensures that these products are not on the shelves at all. Banning chemicals is not always politically feasible. For example, Key West attempted to ban sunscreen containing oxybenzone and octinoxate, which in reaction Governor DeSantis signed a bill stating local governments may not ban any chemicals in sunscreen. On the other hand, Hawaii enacted a statewide ban on the sale and distribution of sunscreens containing oxybenzone and octinoxate.

POLICY RECOMMENDATION

While a ban of the most harmful chemicals is the most efficient and directly effective, the political feasibility means that it may not take place at the scale that is needed to protect the reefs. Furthermore, banning oxybenzone and octinoxate would boost the sale of other sun filtering chemicals that are potentially harmful as well. For this reason, a term regulation with a complete toxicology analysis of all the FDA approved filters may be a more beneficial policy. Not only is there evidence of public willingness to purchase the newly labelled reef safe sunscreen, but there is also political feasibility that is lacking from the complete ban option.

While the two policy alternatives were evaluated thoroughly given the data researched, there are limits to the study. The political feasibility portion could have been improved with more data regarding the political makeup of each state. While the issue currently seems to be split between political parties, more research needs to be done on similar laws in the past. This would result in a better understanding of which states will be willing to pass a ban. A previous example of the chemical testing standardization process would also have been helpful. This would have given me a better understanding of the timeline associated with the efficiency criterion.

FINAL CONCLUSIONS

In this project I conducted research to suggest that oxybenzone, a chemical in sunscreen, has negative effects on the embryological development of sea urchins. Sea urchins, being an important positive factor in coral reef recovery, have great ecological importance. They must be protected in order to protect the diminishing coral reefs. I suggest further research be done to find more concrete results. I plan to share my research and protocols with the biology department's Undergraduate Aquatic Research Lab for use in future student projects.

This past year I was able to conduct both biological research and research in the field of policy analysis. I enjoyed getting to explore a different field, public policy, through this project. I worked to discover what would be the best possible policy to enact in order to protect both urchins and coral reefs. As I move into the post-graduation time in my life, I am recognizing the importance of exploring as many fields as I can. I plan to go to graduate school next, where I will decide if I want to pursue research or a more professional area of marine biology. Completing this project gave me valuable experience in both that will allow me to make informed career decisions in my future.

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