Death of A Star: The Sea Star Wasting Disease Epidemic and its Impact on Kelp and Climate Change

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ABSTRACT

Sea star wasting disease (SSWD), originally identified in 2013, is an epidemic impacting 20 species of sea stars along the west coast of North America. Two of the most impacted species, *Pisaster ochraceus* and *Pycnopodia helianthoides* are keystone species. The loss of these sea stars impacts oceanic life. Literature reviews were conducted from January to May 2022 to investigate the effect of SSWD on the food web of sea stars and decline of kelp. The apex predators of the ecosystem, *P. helianthoides* and *P. ochraceus*, have decreased drastically, while their prey, urchins, have increased immensely. As a result, kelp, a producer, has decreased significantly. The decline of the keystone species is highly concerning and could have drastic ecological impacts. The loss of kelp is extremely damaging for both marine life and Earth itself. If sea stars continue to decline, the amount of carbon dioxide and loss of kelp will become increasingly problematic for the ocean and health of the planet.

Introduction

Sea star wasting disease (SSWD), originally identified in 2013, is now an ongoing epidemic that has impacted 20 species of sea stars all along the west coast of North America (Montecino-Latorre, 2016). While such outbreaks are not a new occurrence, previous epidemics were notable for being spatially contained. The current surge of the disease however, is spreading much further, is more persistent, and is thus contributing to a mass mortality of sea stars (Miner, 2018).

There is no singular cause identified by scientists that explains the origins of SSWD, but there have been some theories. Early research suggested that SSWD is caused by a densovirus called Sea Star-Associated Densovirus (SSaDV), but later work proved that SSaDV affected only one species of starfish, the *Pycnopodia helianthoides* (Hewson, 2018). Another theory proposed that the spread of SSWD was due to an ecological interaction between the starfish and microorganisms such as bacteria. In this scenario, SSWD served only to weaken the starfish, allowing bacteria to infect and ultimately kill them (NBCUniversal News Group, 2014). The decaying starfish bodies then allow even more bacteria to grow, endangering nearby starfish, thus creating a deadly cycle (Rossillo, 2021). An additional theory asserted that effects of climate change, most notably increased ocean temperatures, have been aligned with phytoplankton blooms, which may be intoxicating the ocean and therefore endangering sea stars (Koumoundouros, 2021). The current consensus to all of these theories is that a pathogen is most likely connected to SSWD, however other environmental components may also be taking part (Hewson, 2018).

No matter the cause, symptoms of SSWD are extremely serious and deadly. A starfish with SSWD would initially show symptoms of lethargy, but soon would develop skin lesions, loss of turgor, and arm loss before disintegration and death (Henson, 2014). Scientists have attempted to treat the disease by injecting infected sea stars with antibiotics. Unfortunately such attempts have been met with limited success (Wahlstrom, 2015).

Among some of the most affected are two keystone species of starfish: *P. ochraceus* and *P. helianthoides*. A keystone species means that the species are so crucial to the ecosystem that if eliminated from the environment, other

organisms in the food web would face repercussions, posing a huge threat to subsequent organisms (Blue Ocean Society 2019). This means that the loss of sea stars has implications for oceanic life, especially when considering food chains, predators, and prey that impact kelp.

Oceanic kelp, a large brown algae, can usually be found in shallow, rocky coasts. Their ecosystems provide shelter for many species, including fish, crabs, and other marine life (Steneck, 2002). Kelp plays a vital role in the global carbon cycle, specifically in carbon dioxide sequestration, or the capturing and storing of carbon dioxide through photosynthesis (Cage, 2018). Carbon dioxide is a greenhouse gas, or a gas that traps energy from the sun inside the Earth's atmosphere. While a little carbon dioxide is necessary to heat the planet to an acceptable level, too much can cause overheating and contributes to the massive climate change problem (National Aeronautics and Space Administration, 2022). Carbon dioxide sequestration by kelp has been highlighted by researchers as offering benefits over other forms of climate interventions, such as reforestation, the process of growing trees (Cage, 2018). This is because other forms of sequestration are susceptible to releasing carbon dioxide back into the environment due to unplanned human disturbances, while kelp remains protected due to their location in the ocean. Kelp's capacity for carbon dioxide sequestration that is permanent makes it powerful in reversing climate change (Cage, 2018).

This research aims to identify the impact of SSWD on sea stars and their related oceanic food chains, in ways that are detrimental to kelp forests and therefore the health of the planet.

Methods

A series of literature reviews were conducted from January to May 2022 to investigate the effect of SSWD on the food web of sea stars and decline of kelp. Searches were made via Google Scholar using modifications of the following keywords: 'sea star wasting disease (SSWD); 'sea stars (*P. helianthoides*, *P. ochraceus,* decline)'; 'kelp (temperature, decline, ecological value); 'prey (urchins, temperature, increase, ecological value)'.

Preference was given to peer-reviewed publications available in the public domain. The articles were reviewed for details regarding the SSWD epidemic, with particular attention paid to marine food chains impacted by SSWD and the correlation between SSWD and the declining quantity of kelp forests. Additionally, a database from the University of California at Santa Cruz (2020) was accessed which contains three decade's worth of information on SSWD and the starfish it impacts from over 200 intertidal sites.

Results

While SSWD affects over twenty species of sea stars, there are a select few with the highest mortality rate (see Figure 1): *Solaster dawsoni*, *Evasterias troschelii*, *Pisaster brevispinus*, *Pisaster ochraceus*, and *Pycnopodia helianthoides* (University of California - Santa Cruz, 2018). The decline of the *P. ochraceus* star has led to a massive change in the mussel population, a main component of the stars' diet (Menge, 2016). The mussel population, which feeds on kelp, has increased since 2013 during the decline in sea stars. One of the dangerous consequences of the increase in mussel population is a larger threat to kelp, which is prey to mussels. *P. helianthoides* is also linked to a decrease in kelp; these stars eat urchins, which in turn consume kelp. This means that similar to *P. ochraceus*, the loss of *P. helianthoides* is also posing a threat to oceanic kelp (see Figure 2), and therefore represents a potential downward spiral for the environment (Friedlander, 2016).

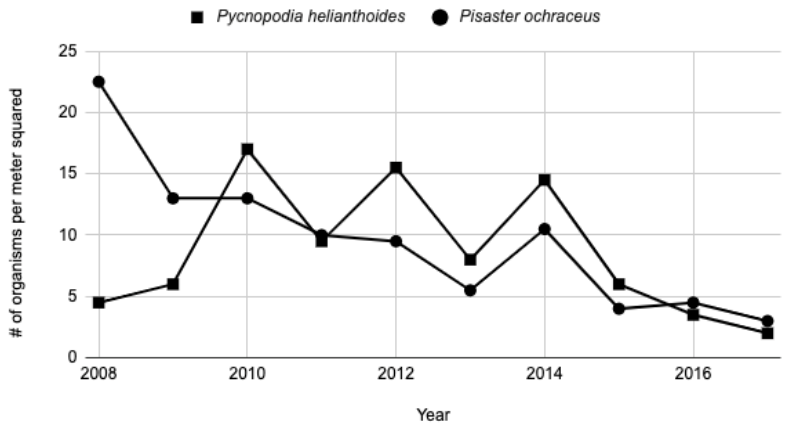

Figure 1. Decline of Sea Stars (2008-2016). The population decline of sea stars *Pycnopodia helianthoides* and *Pisaster ochraceus* from 2008-2016. The SSWD epidemic was identified in 2013. This figure was adapted from the National Park Service (2021).

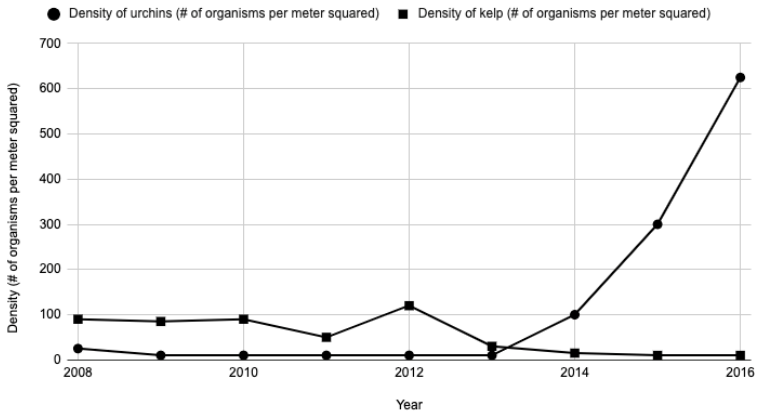

Figure 2. Purple Urchin Growth and Kelp Decline (2008-2016). The population decline of kelp and increase in the urchin population from 2008-2016. The SSWD epidemic was identified in 2013. This figure was adapted from Science World (Ferrara, 2019).

Data from various oceanic studies (Bonaviri 2017,; McPherson 2021,; University of California - Santa Cruz, 2022; and others) have documented that since 2013, there have been changes in the populations of the various organisms implicated in this downward spiral. *Pycnopodia helianthoides* and *Pisaster ochraceus*, the apex predators of the ecosystem, have decreased by 90.5% and 95% respectively, while their prey, urchins, have increased by 10,000%. As a result, kelp, a producer (an organism which creates its own food), has decreased by 95% (Table 1). Due to their close proximity, it can be inferred that these statistics are a result of the loss of sea stars from SSWD. Because of the lack of stars, their prey, mussels and urchins, have run rampant and been able to reproduce uncontrollably. Kelp is threatened as it is prey to these recently increased populations.

Kelp also provides habitat for other organisms; UCSC found over 1,200 species in kelp forests during monitoring between 1999-2020 (MLPA Kelp Forest Taxon) indicating that the destruction of kelp is harming other organisms outside of this particular food chain.

Table 1. Change in the population of organisms across trophic levels in kelp forests (2013-2022). The SSWD epidemic was identified in 2013 (Nair, 2020; Santini, 2014; Associated Press, 2019; Fox, 2021).

	Pycnopodia helianthoides	*Pisaster ochraceus*	Urchins	Kelp
Trophic Level	Keystone Predator	Keystone Predator	Primary Consumer	Primary Producer
Decreased or Increased?	Decreased	Decreased	Increased	Decreased
Change in Population (%)	90.5%	95%	10,000%	95%

Discussion

The decline of keystone species *P. ochraceus* and *P. helianthoides* is highly concerning as the decline of these species could have drastic ecological impacts. In fact, ecologists have noted that *P. ochraceus* in particular can greatly influence the intertidal community it inhabits (University of California - Santa Cruz, May 2022). The results of this review show a sizable increase in sea urchins and a significant decrease in the kelp population, which supports the concerns already raised by ecologists. *P. helianthoides* is already a critically endangered species on the brink of extinction (Gravem 2020). If the SSWD epidemic continues, this may be the fate for other species like the *P. ochraceus*. Collectively, this will continue to pose a threat to kelp forests.

Carbon dioxide is a greenhouse gas, a gas that traps energy from the sun inside the Earth's atmosphere. While a little carbon dioxide is necessary to heat the planet to an acceptable level, too much can cause overheating (National Aeronautics and Space Administration, 2022). This is an extreme issue as kelp's ability to sequester so much carbon dioxide is incredibly valuable, year after year. For example, kelp can sequester up to twenty times more carbon dioxide per acre than land forests (Hurlimann, 2019). This means the loss of the producer will only increase global warming, which can have deadly effects (Denchak 2022).

Additionally, kelp is home to many organisms, such as fish, invertebrates, and even gray whales (National Oceanic and Atmospheric Administration, 2009). This means that the loss of kelp is detrimental to many species, making it harder for them to survive as they no longer have a habitat to thrive in. Losing so many species can disrupt the marine food web, posing threats to even more organisms, beyond the kelp forests. It can even affect species above ground, such as the birds who eat the fish who live in kelp. Without kelp to shelter them, birds may be able to see the fish easier and consume more, creating even more chaos in the food web.

With these keystone species declining, many organisms are being affected, leading to the planet itself being in danger. More information needs to be researched to discover how to stop the spread of SSWD and the decline in kelp, among other things. These are crucial to ending this epidemic and the effects that come with it.

Conclusion

This research aimed to identify SSWD's impact on oceanic food chains including kelp, and therefore the health of the planet. Our review of the existing literature suggests that the impact of this epidemic is harmful to both organisms and the environment itself. In particular, the deaths of two keystone species, *P. ochraceus* and *P. helianthoides*, seem to play a significant role in this ecological decline through their effects on urchins and mussels, and eventually kelp forests.

In order to help understand and stop the damage being created to the ecosystem and planet, the following questions need to be explored. Firstly, there should be more investigation into kelp propagation, which may not only help to make the proportion of urchins and mussels to kelp better for the ecosystem, but would also aid in carbon dioxide sequestration as a whole. Secondly, further clarification is needed on what is causing SSWD and what can be done to stop or reverse this epidemic. If this could be discovered, it would help prevent SSWD from negatively affecting more stars and therefore the ecosystem. Thirdly, it is important to explore what other organisms are affected by the death of sea stars, and what the implications of their loss or increase are on the ecosystem and planet. Finally, further research is needed to understand what will happen or what has already happened to organisms that call kelp their home as changes in their population could cause even more damage to the ecosystem.

The loss of kelp, occurring through a chain of events starting with SSWD, is extremely damaging for both marine life and Earth itself. If sea stars continue to decline, the amount of carbon dioxide and loss of kelp will become increasingly problematic, fueling the many existing concerns about both the ocean and health of the planet.

Limitations

To echo other researchers, while SSWD is certainly causing a decrease in stars and leading to this downward spiral, it is unknown if there are other contributing factors as well. For example, there may be other reasons as to why mussels and urchins are increasing while kelp is simultaneously decreasing. Additionally, there are many factors such as temperature, salinity, and ocean acidification that could be contributing to a decrease in sea stars, separate to SSWD.

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