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Sea Star Wasting: Investigations in Disease Ecology and Environmental Dynamics

Keywords: Sea Star Wasting Disease (SSWD), Wasting Asteroid Densoviruses (WAaDs), elevated temperatures, hypoxia.

A literature review was conducted to present information on current and preceding works regarding sea star wasting disease (SSWD), more accurately termed as a syndrome. This project aimed to provide a background surrounding ecological impacts and disease ecology as it is related to sea star wasting disease. While much research has been done to satisfy these critical areas in knowledge surrounding SSWD, extensive work is still needed to further the understanding of microbial relationships to SSWD, multi-host system dynamics, species-species variability, immunology of asteroids in response to wasting, and larval susceptibility and transmission.

Sea star wasting disease (SSWD), more accurately represented as a syndrome, is described as an onset of abnormal morphological characteristics which would include: loss of bodily turgor, lesion development, autotomy, degradation of mutable connective tissue, which would then lead to further visible disintegration and ultimately death in severe cases. The International Union of Conservation of Nature has reported the death of billions of sea star individuals throughout the decade it has been predominant, especially throughout the 2013-2014 mass mortality event (Gravem et al. 2022) that was reported along the Gulf of Alaska, the entirety of the North American Pacific Coastal region, and reaching down to Mexico (Heady et al. 2022).

Following this event ultimately led to the decimation of several keystone predator species, such as *Pycnapodia Helianthoides*, the sunflower sea star. This event rendered the species critically endangered, as highlighted in the International Union of Conservation for Nature (IUCN), which reported a 94.3% global decrease. In the Washington State coastal region, the species experienced a 99.6% population decline alone (Heady et al. 2022). The 2013-2014 mass mortality event resulted in a drastic increase in green urchins, which has the potential for the overgrazing of kelp forest. The loss can lead to declines in biodiversity that depend on kelp for nutrients. Furthermore, the decline in keystone predator species can potentially lead to the eutrophication of water bodies, enriching these habitats with excess nutrients (Oulhen et al. 2022). This can then lead to the overgrowth of algal blooms, leading to anoxic environments.

In an effort to mitigate the impacts of these devastating losses, researchers across a broad range of disciplines have mobilized rapidly to understand the etiology of SSWD, and what can be done to maintain the health and recovery of these asteroid species. Initial uncertainty and speculation has led to misinterpretations of early observations pertaining to the etiology of this syndrome, most notably the hypothesized correlation between densoviruses and sea star wasting. However, subsequent works have reported no consistent evidence for a viral etiology. Wasting Asteroid associated Densoviruses (WAaDs) have been found in both asymptomatic and affected asteroids, with higher viral loads observed in sick asteroids. Viral challenge experiments testing whether viral sized homogenates (<0.2 μm) from symptomatic tissues elicit SSWD did not yield any evidence in the Hewson et al. study (2018). Furthermore, this study explains that Sea Star associated Densoviruses (SSaDVs) decay after release and before contacting any new hosts. This suggests that high density populations may transmit asteroid densoviruses through direct contact between asteroids.

With concerns of drastic changes in water temperature and precipitation, the correlation between these two variables and SSWD has been investigated. Smith et al. (2023) has recently reported that elevated temperatures (especially rapid changes in temperature) has shown to exacerbate wasting in *A. rubens*. Interestingly, the report mentions that size was found to have a significant relation in disease expression, with larger individuals showing more severe disease signs. Both water temperature and precipitation patterns had also been investigated into whether these events had links to wasting, though ultimately led to no consistent pattern. Onset of sea star wasting during the 2013-2014 mass mortality event occurred in both above and below average measures. It is suggested that drastic changes in water temperature and/or precipitation may further exacerbate wasting in asteroids (Hewson et al., 2018. Oulhen et al., 2022).

As an extension of elevating water temperatures as a concern in climate change, hypoxic conditions were found to have a correlation with a shift in microbial compositions near respiratory surfaces, that would then lead to worsening of wasting (Aquino et al., 2021). Enhanced anaerobic bacterial activity was found to have pronounced organic matter decomposition across respiratory surfaces, such as mutable connective tissue in asteroids. From a physiological standpoint, decreased dissolved oxygen was observed in depleted oxygen-treated containers that held asteroids, which led to increased lesion development. This decrease in dissolved oxygen can lead to low respiration and physical stress, increasing the risk of wasting.

The link between heavy rainfall and sea star wasting has been examined, as heavy precipitation events (especially after droughts) have higher potentials to carry larger concentrations of pathogens into coastal waters. This dynamic had implications in recent sea otter mortality events and was directly linked to microcystins (Hewson et al., 2018). Asteroid tissues affected by wasting were examined, and although concentrations of microcystins were highest in tissues of *P. helianthoides* and lower in another affected species *P. ochraceus*, there was no significant relationship (Hewson et al., 2018).

Overall, while much research has been done to fill in critical gaps of knowledge, especially throughout the previous decade wasting has been predominant, extensive review is needed to further the understanding of potential microbial relationships to sea star wasting disease and asteroid physiology in a rapidly changing environment. It is clear that this condition is not the cause of one single causative agent (or condition), but rather a myriad of biotic and abiotic factors. Insight into monitoring of asteroid populations (both healthy and sick) may give more information on how different environmental factors (both biotic and abiotic) can play complex roles to eliciting sea star wasting disease.

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Sea Star Wasting: Investigations in Mass Mortalities of Over 20 Asteroid Species

FHL 432 | Marine Invertebrate Zoology
Roman Tanner
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What is Sea Star Wasting?

A set of abnormal morphological signs

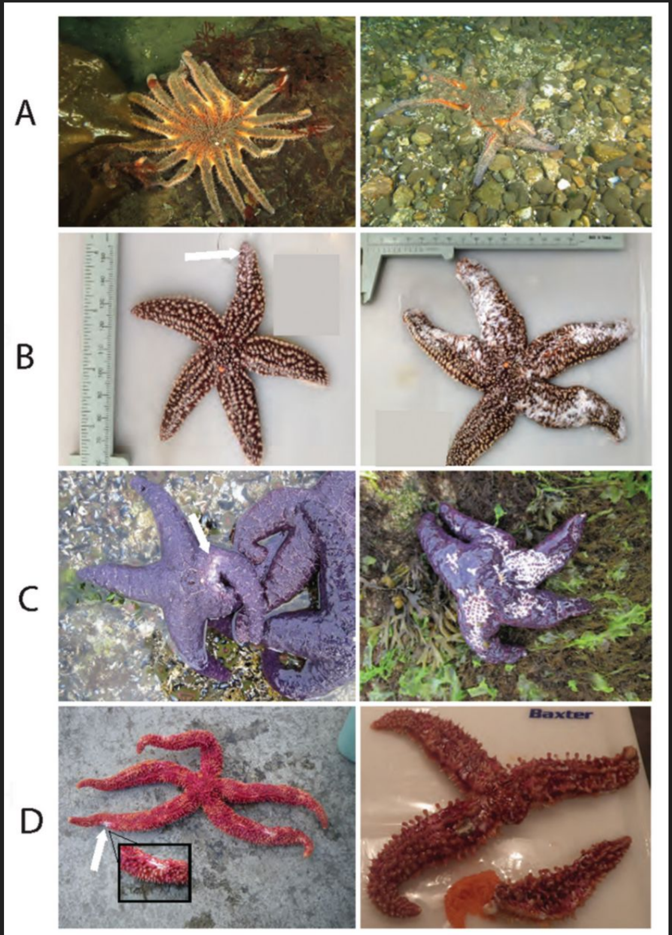
- Loss of bodily turgor, lesion development, autotomy, degradation of connective tissue, visible disintegration.

Primarily affects members of the class *Asteroidea*

Has killed many *billions* of sea star individuals (Gravem et al., 2022)

Initially thought to be the result of a *viral* agent (more on this later)

Figure 1: Shows healthy (on left) and sick (on right)



Oulhen et al. 2022

https://youtu.be/kUfBBOwab1M?si=IIPNINCGL8DQz__2

2013-2014 Mass Mortality

Affected over 20 species affected (e.g *Pycnapodia Helianthoides*, *Pisaster ochraceus*, *Evasterias troschelii*, *Asterias Rubens*, etc.)

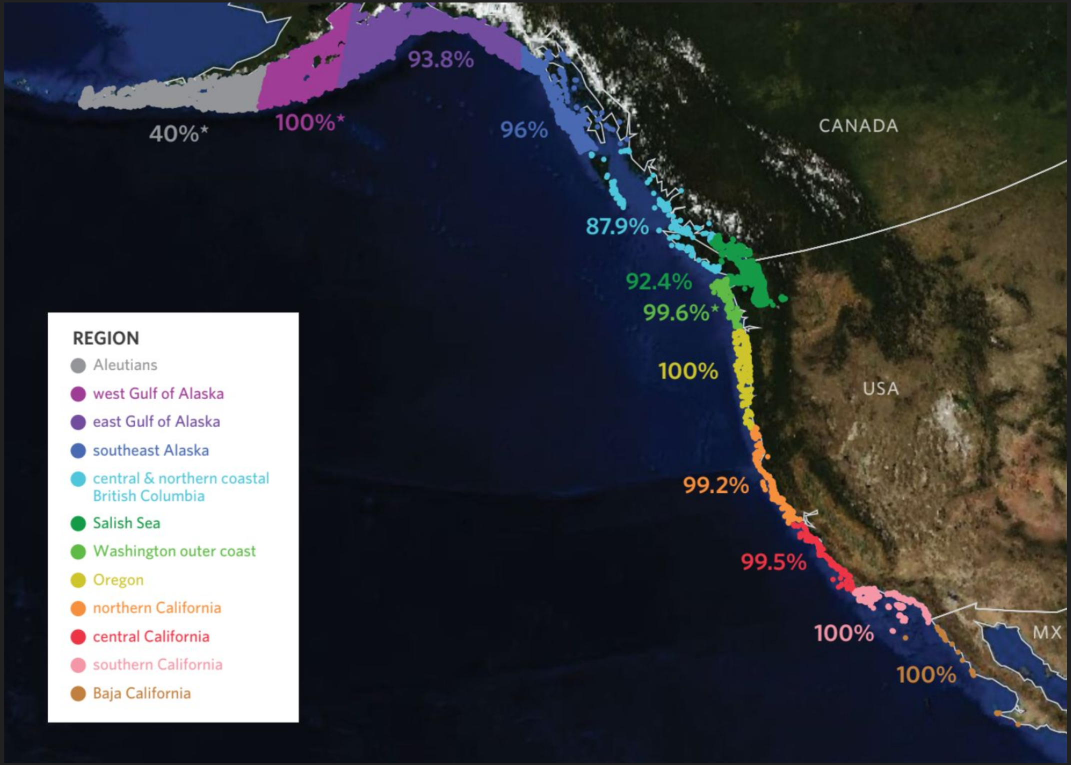
Rendered keystone predator *Pycnapodia Helianthoides* (Sunflower Sea Star) critically endangered – 94.3% global decline (Gravem et al. 2021, Hamilton et al. 2021)

Massive die-offs reported throughout the North American Pacific Coast (Gulf of Alaska to Mexico).

No event previously reported matched this severity

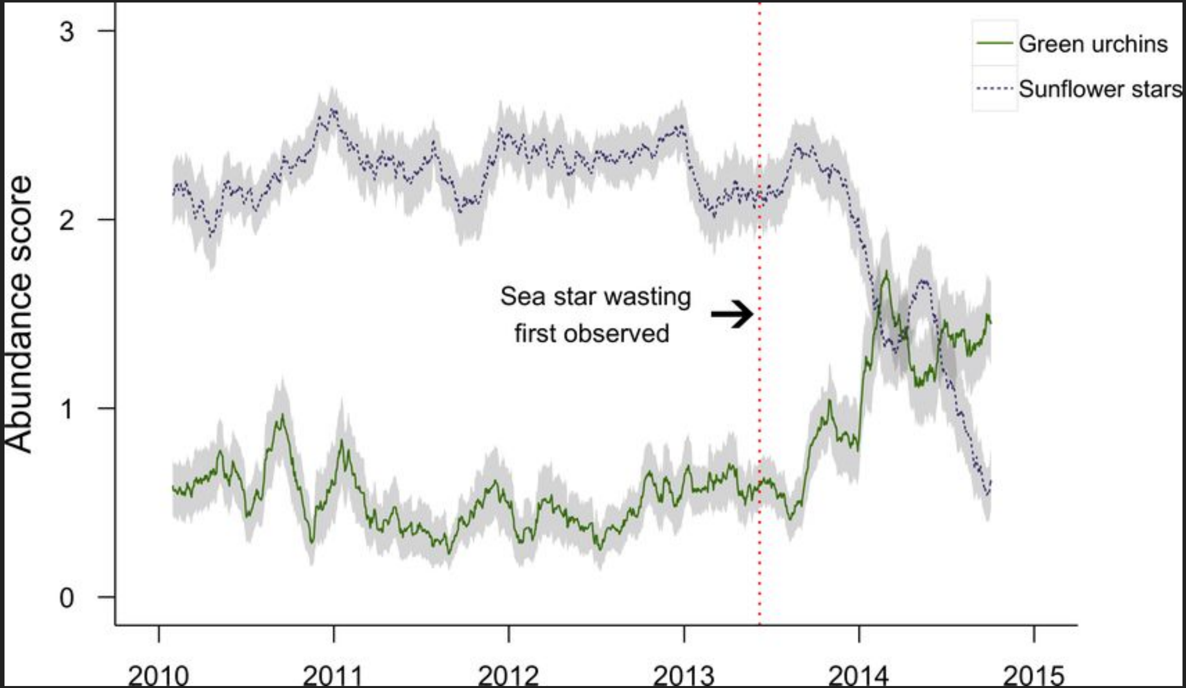
Confusion and speculation amongst researchers led to many misrepresentations, most notably the idea of a densovirus causative agent (Oulhen et al. 2022).

Figure 2: Massive Die-offs on the West Coast



Heady et al. 2022 *Roadmap to Recovery for the Sunflower Sea Star*

Figure 3: Ecological Impact of SSWD



Decline in Asteroids may lead to…

- Increase in Urchin populations
- Potential overgrazing of kelp forests

And many more consequences…

Schultz et al. 2016

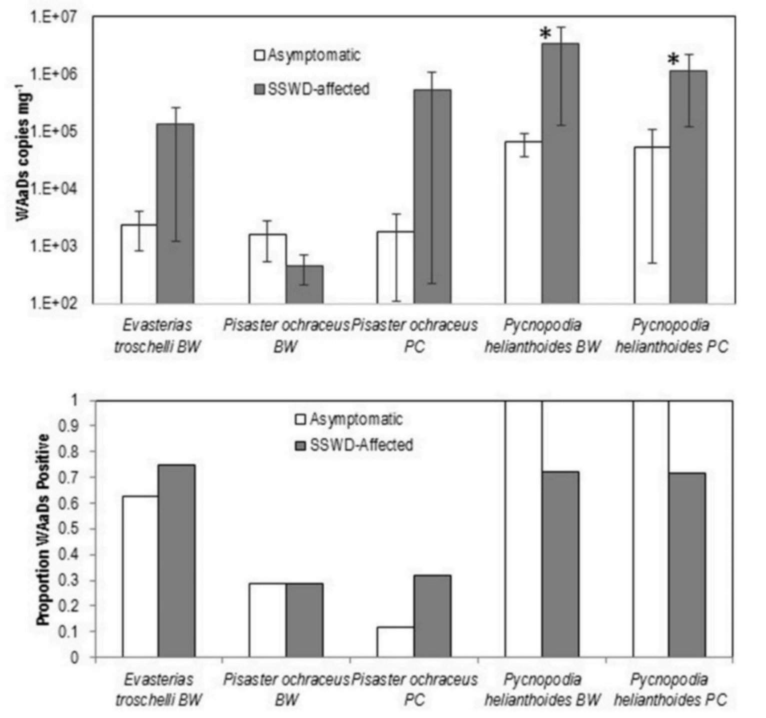
What Do We Know?

Overview of Findings

1) No linear progression - variation in signs (Oulhen et al. 2022)
2) As of yet, no singular causal agent for SSWD
3) Viral pathogens unlikely (Hewson et al. 2018)
4) Temporal and spatial etiology is inconsistent
5) Behaviors observed (sick vs healthy) is overlap
6) Microbial activity from elevated organic material may elicit signs of SSWD (DelSesto, Jessica. 2015)
7) Histology points to visible edema and vacuolation (DelSesto, Jessica. 2015)
8) Environmental factors may contribute or exacerbate SSWD
9) Larger asteroids are more susceptible/show more severity than smaller asteroids
10) Evidence points to multi-host dynamics

Let's go over a few…

Figure 4: Correlation with WAaDs



Literature pointed to Wasting Asteroid associated Densoviruses (WAaDs)

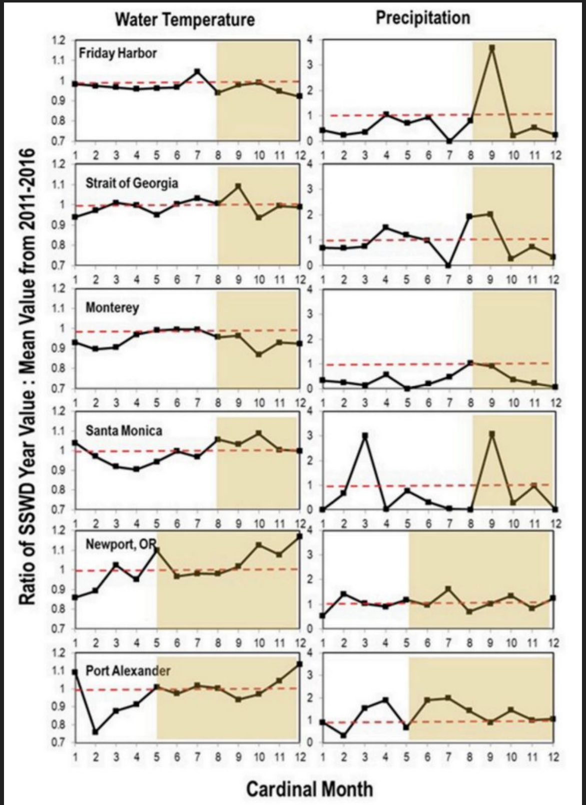
Common in *both* sick and healthy

TLDR: Data is not sufficient enough to prove a viral causative agent

- Otherwise: higher proportion WAaDs positive in sick than healthy

Hewson et al. 2018

Figure 5: Water Temperature and Precipitation



No consistent pattern - onset occurred in both above and below average variables

Data did not point to either an elevation or depression in either variable to elicit SSWD

TLDR: Drastic changes in water temperature/precipitation may *exacerbate* SSWD

Hewson et al. 2018

Figure 6: Correlation with Hypoxic Conditions

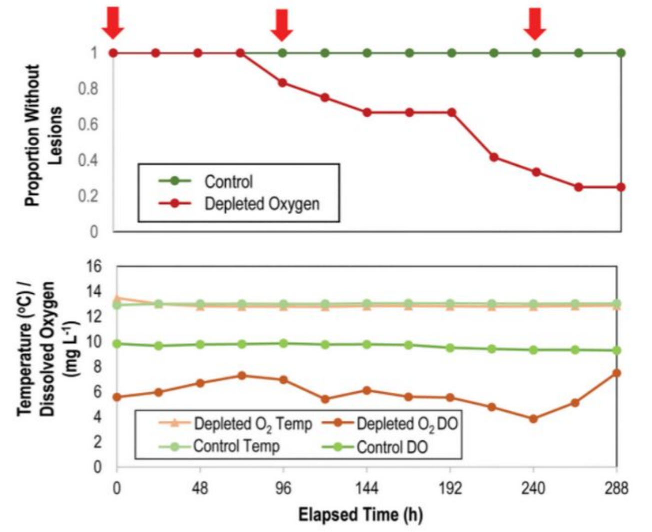


FIGURE 7 | Proportion of grossly normal *Asterias forbesi* (*n* = 12 per treatment) incubated in normoxic and depleted oxygen water (top) and variation in temperature and O_2 in incubation aquaria (bottom) over time. The red arrows at top indicate samples which were included in analysis of microbiome composition (see **Supplementary Figure S6**).

Overall:
Increased lesion development in depleted oxygen treatments

Decreased dissolved oxygen was observed in depleted oxygen treatments

TLDR: Low oxygen → low respiration → physical stress

ADDITIONALLY: Low oxygen → favors anaerobic bacteria → faster decay → may trigger SSWD (Aquino et al. 2021)

Aquino et al. 2021

Challenges in Research

- Koch's Postulate
- Species-Species Variability
- Physical/behavioral overlap between sick and healthy

And many more…

Conclusion

While much research has been done to fill in critical gaps, extensive review is needed to further the understanding of:

- Microbial relationships to SSWD
- Multi-host systems
- Species-Species variability
- Immunology in response to SSWD
- Larval Susceptibility and transmission

To name a few…

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