Sunflower Sea Stars Play a Critical Role in Kelp Forest Resilience

Based on 4 years of scuba surveys on the Central Coast of B.C., our study shows that while sea otters rapidly consume **large** sea urchins and trigger the rapid recovery of kelp forests, sunflower sea stars (*Pycnopodia helianthoides*) play a key role in enhancing the resilience of kelp forests by consuming **small** and **medium** urchin prey left unconsumed by sea otters.

We found that…

Compared to sea otters, sunflower sea stars are MORE EFFECTIVE predators of medium (4-7 cm) and small (≤ 3 cm) sea urchins. The annual mortality rate of medium urchins at reefs with sunflower stars was 1.5x higher than medium urchin mortality at reefs with only sea otter predators, and 4x higher than reefs with no major urchin predators.

When sunflower stars are present on rocky reefs, the densities of medium and small urchins are low (<1 per m^2). But *Sea Star Wasting Disease* triggered the collapse of sunflower star populations on the Central Coast in 2015, and we observed a corresponding 311% increase in the density of medium-sized urchins across all reef sites.

Kelp density was highest at reefs with BOTH sea otters AND sunflower sea stars. The loss of sunflower stars from kelp forest reefs due to *Sea Star Wasting Disease* corresponded to a 30% decline in mean kelp density, and higher kelp variability (within and across reefs).

Sea otters are expanding their range on the Central Coast of BC, arriving at new rocky reef sites and foraging primarily on large (≥ 8 cm) red sea urchins.

Following sea otter arrival, we observed an 89-98% decrease in the mean density of large urchins within 1 year.

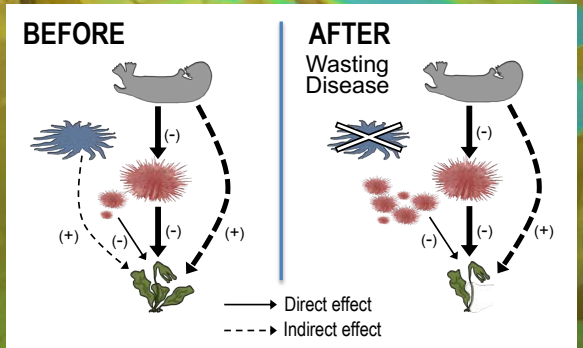
Mean kelp density was high (5-7 stipes/m^2) across reefs with sea otters, and low across reefs without sea otters (0-1 stipes/m^2). After otter arrival, surface kelp canopies expanded by 2.9x and were more dense compared to the years prior.

Our findings support…

Sea otters and sunflower stars are complementary in the sizes of sea urchins they consume; otters prefer large energy-rich urchins and sunflower stars consume medium and small urchins they can physically digest.

Complementary predation on urchins by sunflower stars has a positive indirect effect on subtidal kelp abundance, in addition to the larger indirect effect that otters have on subtidal kelp abundance.

By consuming medium and small urchin prey left unconsumed by sea otters, **sunflower sea stars play a key role in ENHANCING the resilience of kelp forests on rocky reefs.**



Our methods

We conducted scuba surveys on 11 rocky reefs on the Central Coast of BC that varied in their status of sea otter occupation and were monitored for 2 years **before** and 2 years **after** the onset of *Sea Star Wasting Disease* (mass mortality of sunflower stars). We used these data and a population model (structured across time and space) to examine how urchin densities and sizes, urchin mortality rates and grazing capacity, and kelp densities vary with sea otter and sunflower star presence/absence.

Why these results matter!

1. While sea otters are known to be important predators of sea urchins, keeping kelp forests from becoming over-grazed, our results show that ***it's not just about otters***! We reveal the previously underappreciated role that middle-level predators (mesopredators), like the sunflower star, play in mediating this "classic" cascade of interactions.

2. ***Our results provide one explanation for why sea otter-triggered kelp forest recovery may be different across geographic regions***. In regions where sunflower stars are present (e.g. BC and Southeast Alaska), the suppression of medium and small urchins at urchin-dominated reefs may facilitate the rapid kelp recovery that occurs following sea otter arrival. In regions with no sunflower stars, the prevalence of smaller urchins that remain unconsumed following sea otter arrival/foraging might help explain why kelp recovery occurs more slowly.

3. Kelp forests are one of the world's most productive ecosystems, and ***increased knowledge of what enhances their resilience is important to inform local ecosystem monitoring and management***.

4. This study highlights that ecological surprises – like mass mortality events – are important in ecology because they ***can reveal new insights*** (i.e. species interactions) ***that lead to reformulating our views of community dynamics.***

STUDY TITLE: **Sudden collapse of a mesopredator reveals its complementary role in mediating rocky reef regime shifts**
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PUBLISHED IN: **Proceedings of the Royal Society B**. July 2018.

Thanks/Giáxsixa/Gianakaci to the Heiltsuk and Wuikinuxv First Nations for supporting this work in your territories. We also thank the Hakai Institute and staff for tremendous support, and Simon Fraser University, BC Parks, NSERC, Pew Charitable Trusts, the Canadian Foundation for Innovation. We are also indebted to many colleagues and friends who helped with field monitoring. Otters photo: Grant Callegari, All other images: Jenn Burt