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DIVERSITY AND DISTURBANCE: HOW MUSSELS AND SEA STARS STRENGTHEN THE ROCKY INTERTIDAL COMMUNITY

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YOUNG REVIEWERS:

FERN
AGE: 11

LENORE
AGE: 14

SEWARD MIDDLE SCHOOL
AGES: 11–13

In the rocky intertidal zone, tides and rocks set the stage. Together they create habitat for a diverse community of species adapted to a world both underwater (high tide) and exposed to air (low tide). In some protected areas, like national parks, we study rocky intertidal ecosystems as vital signs of nature's health. Studying them helps us understand the impact of disturbances, which play an important role in shaping these communities. Some disturbances, like the tides, happen daily. Others, like diseases, might happen once every decade. This article is about how tides and diseases affect two important members of rocky intertidal communities—mussels and sea stars. We explain the roles these organisms play and what happened when ochre sea stars, an important species in these habitats, suffered a major disease outbreak. Last, we emphasize the importance of

protecting these vital ecosystems so we can continue to learn about the health of the natural environment.

THE ROCKY INTERTIDAL ZONE

All over the world where the ocean meets the land, we find intertidal ecosystems. "Intertidal" refers to land that gets covered and uncovered by the tides (Figures 1A,B). Where the land is rocky, we find rocky intertidal ecosystems, where tidepools often occur. Tidepools contain unique lifeforms that we do not often find in other intertidal systems like sandy beaches or mudflats. On the western coast of North America, the rocky **intertidal zone** is shaped by tides that have four phases every day: two low tides and two high tides. These tides create four zones within the rocky intertidal region (Figure 1C), (1) spray zone (dampened by ocean spray, high waves, and storm surges), (2) high intertidal zone (underwater only during very high tides), (3) middle intertidal zone (exposed to air between high and low tides), (4) low intertidal zone (almost always underwater). Without these four habitats, the rocky intertidal zone would not be as biologically diverse as it is.

INTERTIDAL ZONES

The different spaces of the shore area between the lowest water level and the highest water level, where the water level is determined by the tides.

Figure 1

An intertidal site in Northern California (United States). **(A)** The site at low tide, when many rocks and surfaces are exposed. **(B)** The site at high tide, when the water covers most surfaces. **(C)** A closer look, showing the four types of habitats or "zones" that exist in the intertidal site.

SEA STAR WASTING SYNDROME

Disease of many sea star species, with symptoms including lesions, decaying tissue, and eventually death. The recent outbreak is the largest marine disease die-off ever recorded.

BIODIVERSITY

All the different kinds of life found in one area.

Like the tides, diseases also shape intertidal communities. Diseases often harm specific species, which in turn affects community relationships. A recent disease called **sea star wasting syndrome** affected many sea star species along the western coast of North America [1], and one of those species (the ochre star) plays an important role in shaping rocky intertidal communities. Both forms of disturbance—tides and disease—are natural engineers that change these communities. While tides enhance **biodiversity** by creating multiple zones, disease tends to reduce it.

WHO STUDIES THESE THINGS?

United States National Park Service scientists study rocky intertidal zones in collaboration with other scientists, as part of the Multi-Agency Rocky Intertidal Network [2]. Together, we look at marine animals and seaweeds, plus sea-surface temperatures. Tracking sea-surface temperatures is important because it gives us information about how global warming is impacting marine organisms. Sea-surface temperatures might also be important for understanding sea star wasting syndrome.

By keeping a close eye on rocky intertidal communities, we can understand how they respond to disturbances like tides, disease, temperature changes, storm surges, oil spills, or fishing. We can use this information to make smart decisions about how to manage parks with rocky intertidal ecosystems.

IMPORTANT INVERTEBRATES: MUSSELS AND SEA STARS

Every year, in national parks along the western coast of the United States, we survey rocky intertidal communities. We take pictures and measurements, often going out very early in the morning at low tide. Some species are common and easy to find, but some are **cryptic**, or difficult to find. Many of these are small species like algae or tiny **invertebrates** (like snails) that live within mussel beds that often cover much of the middle intertidal zone. In a mussel bed, we often find hundreds of these hidden species in areas no bigger than a small backyard! These cryptic critters are important food sources for many larger animals.

CRYPTIC

Characterized by coloration or markings that camouflage an animal in its natural environment, often helping to reduce predation.

INVERTEBRATE

A cold-blooded animal with no backbone.

Like the cryptic animals they support, mussels are also invertebrates. The most common mussel in this part of the United States is the California mussel (Figure 2A). California mussels are well-adapted to the rocky intertidal zone. They occupy mostly low and middle intertidal habitats where there is enough water to keep them from drying out. They form huge beds in which thousands of them live packed together. When waves come crashing in, mussel beds slow down the water that passes through them, which reduces wave impacts for other animals. California mussels make little threads that attach them to each other and to the rocks they live on, to keep them in place. These mussel beds create habitat for cryptic animals and trap the food that those animals eat. Not only do California mussels provide food for these secretive animals, they themselves are food for predators like sea stars and some snails. California mussels are right in the middle of the rocky intertidal food web, providing essential resources to other members of the community.

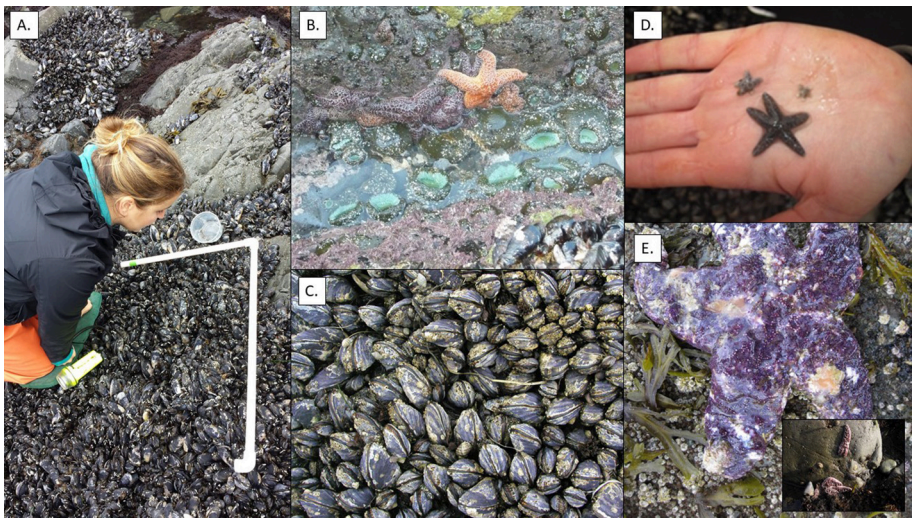

Figure 2

(A) A researcher measuring mussel beds. **(B)** Sea stars (orange and purple) in a tidepool. **(C)** Up close and personal with mussels. **(D)** Juvenile (baby) sea stars. **(E)** Sea star wasting syndrome, which causes sea stars to "melt" and lose their arms.

The most important intertidal sea star in this coastal area of the Pacific Ocean is the ochre star (Figures 2B–E). Like California mussels, ochre stars are invertebrates that occupy mostly low and middle intertidal habitats. We already know that when we remove ochre stars from the community, California mussel populations increase [2]. This happens because the size of the rocky intertidal habitat is restricted to the area that is covered and uncovered by the ocean each day, space for animals and algae is limited. California mussels are very good at competing for space on the rock. When ochre stars are present, they keep mussel populations in check, creating space for other species to live. But, when ochre stars are missing, mussels can quickly take over open habitat and exclude other species. Ochre stars can thus increase the biodiversity of species that must attach to rock to survive.

Compared to California mussels, which are abundant, ochre stars are sparse and have less **biomass**. Despite their low biomass, their impact in rocky intertidal communities is huge [3]! For this reason, ochre stars are considered a **keystone species**. In fact, ochre sea stars were the first species ecologists used to define the concept of keystone species, which are species that (like the ochre star) have huge impacts despite being low biomass. We now know that all ecosystems—terrestrial, freshwater, marine, and everything in between—have keystone species. The loss of a keystone species has a big impact. Without ochre stars, biodiversity would decrease.

SEA STAR WASTING SYNDROME AND OCHRE STAR RECOVERY

In 2013, scientists at Olympic National Park in the state of Washington (United States) discovered an outbreak of sea star wasting syndrome. This disease had been killing sea stars in large numbers from San Diego

BIOMASS

The total amount or mass of living organisms in a given area or ecosystem. Biomass can refer to species biomass, which is the total mass of one or more species in an area.

KEYSTONE SPECIES

A species with a larger effect on its environment than its biomass suggests, like beavers creating dams making new wetlands, or sea otters eating urchins allowing kelp forests to flourish.

in southern California, all the way to Alaska. No one is sure where this disease came from, but some think there is a connection to high sea-surface temperatures. While it killed many different species of sea stars, one of the hardest hit was the ochre star [1]. When this keystone species declined, what do you think happened to mussel populations? As expected, mussel populations increased in some places, but not all. We are not exactly sure why this is, but we are studying how factors other than the presence of ochre stars can influence how much mussel populations can grow.

Within 2 years after the die-off, ochre star populations started to come back in some places, but not everywhere. Where populations were recovering, there was a new problem: the new ochre stars were all babies, and baby ochre stars do not eat as much as adults (Figure 3). In other words, they do not exert as much **predation pressure** on mussels [4]. Why does this matter? Without the predation pressure from adult sea stars, mussel populations can grow large very quickly. They will out-compete other species that need the same habitat. So, even where the number of ochre stars came back, mussel populations did not decrease right away [4]. The community needed adult ochre stars to make that happen, and it can take 5 years for baby ochre stars to mature into adults. Once ochre stars mature, mussel populations should decrease, and biodiversity of animals and algae attached to the rock should increase again. It is our hope that the baby ochre stars stay free of sea star wasting syndrome and grow up to regain their role as a keystone species.

PREDATION PRESSURE

The effect of predators (organisms that eat other organisms) limiting the number of prey (organisms that get eaten) by eating them.

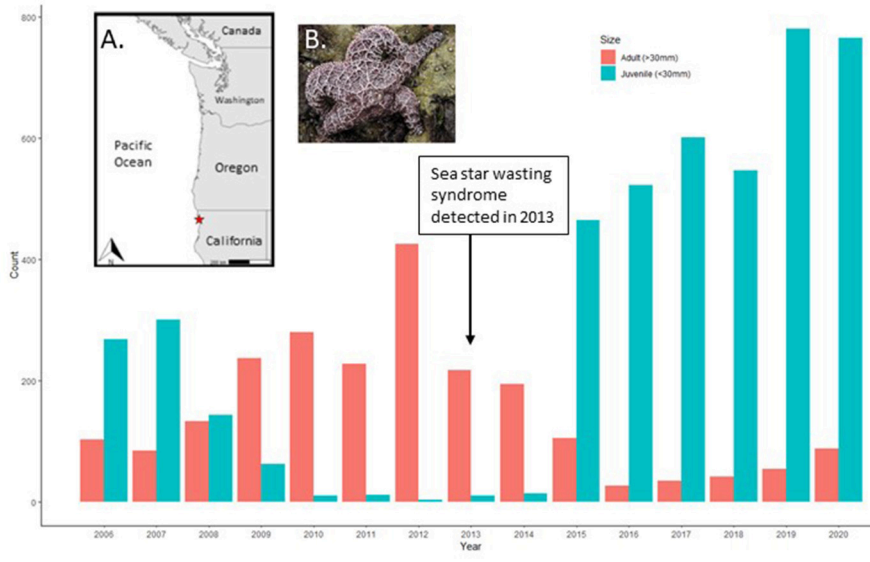

Figure 3

Figure 3

After detection of sea star wasting syndrome in 2013, adult sea stars declined (red), followed by a large rise in juvenile (baby) sea stars 2 years later (blue). **(A)** Location of monitoring in Redwoods National and State Parks on the northern coast of California, USA. **(B)**. The ochre sea star.

Since the disease outbreak, we have continued to survey every year. At Redwood National and State Parks in Northern California, ochre stars seem to be recovering—a good sign for the community! At Channel Islands National Park in Southern California, they do not seem

to be recovering. Why the difference? We do not know yet, but we will keep studying these ecosystems long into the future. The more data we can gather about all the elements shaping rocky intertidal communities, the better our understanding will be. This includes studying the seaweeds, animals, water and air temperatures, and other biological or environmental disturbances.

CONCLUSION

People have been studying rocky intertidal zones for decades, which has given us a clear understanding of what healthy rocky intertidal communities look like. The western coast of North America has keystone species (sea stars), mussel beds, and many cryptic organisms. The tides create four types of habitats, providing a place suitable for every intertidal species. The rocky intertidal zone is a vital ecosystem connecting the ocean to the land.

The United States National Park Service plays an important role in protecting the rocky intertidal zone. As we study the impact of sea star wasting syndrome, we will continue learning. In case sea surface temperature had something to do with this disease, we will watch for disease outbreaks when temperatures are high again. Our work allows us to manage our parks to protect rocky intertidal communities when they are especially vulnerable. As the Earth's climate continues to change and human activities impact rocky intertidal zones, monitoring for changes will be especially important. If you want to get involved, please consider joining **citizen science** groups, so you too can survey these beautiful intertidal communities [2].

CITIZEN SCIENCE

Science done using the general public. Scientists generally guide and assist in empowering local communities to engage in local research or even global studies.

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CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

FERN, AGE: 11

Hi, I am Fern! I am 11 years old and in 6th grade. I am currently homeschooled, and my favorite subjects are English and Science. I like poetry, reading, sketching, fishing, mountain biking, XC skiing, and sledding. I play the mandolin and flute, and I love bluegrass music. I have a goofy and cute golden retriever who loves popcorn. My favorite foods are spaghetti, cupcakes, and Brussel sprout leaves cooked in bacon grease. I am doing this project with my Girl Scout troop.

LENORE, AGE: 14

Hello, I am Lenore, a 14-year-old 8th grader. I am experimenting with pronouns, and currently go by they/them. My favorite animals are the Canadian Lynx, closely followed by Golden Retrievers. I play the clarinet and banjo, and am a huge fan of We Banjo 3. I enjoy walking with my family and dog, and biking (road + mountain). I also enjoy role-playing, drawing, and paint-by-stickers. My dog constantly steals my food. I am doing this project with my Girl Scout troop.

SEWARD MIDDLE SCHOOL, AGES: 11–13

Seward Middle School is nestled on the edge of the ocean and base of stunning mountains. We are an active and tight-knit community that values arts, sports, and taking care of each other. This crew of students is a strong, intelligent, and driven group of ladies! They are competitive dancers, backcountry skiers, amateur botanists, entrepreneurs, master seamstresses, athletes, and more. These ladies are academic and social leaders in their school, setting examples for behavior, study habits, and focus.

AUTHORS

ELLIOT HENDRY

Elliot Hendry is a student of ecology at the University of Wisconsin-Madison, where he is researching desert springs. Elliot grew up in Missouri where he spent lots of time outside. Upon finishing an undergraduate degree in environmental studies, he began working with the National Park Service. After 7 years of working in national parks and forests, Elliot entered graduate school. Elliot hopes to use his research on desert springs to improve the way we appreciate and conserve the diversity of aquatic ecosystems on Earth. In addition to ecology, Elliot loves cycling, running, backpacking, music, and reading.

KARAH N. AMMANN

Karah N. Ammann conducts field research in the rocky intertidal, in partnership with the Multi-Agency Rocky Intertidal Network (MARINe). "Office time" involves exploring one of the most dynamic ecosystems on the planet; and "work" includes participating in biodiversity surveys and monitoring intertidal species along the west coast of North America.

ERIC C. DINGER

Eric C. Dinger is an ecologist for the National Park Service, conducting monitoring and assessment of streams, lakes, and intertidal zones in national parks in southern Oregon and northern California. He grew up backpacking in the mountains and enjoying his time visiting wilderness streams and lakes. During university studies, he fell in love with aquatic invertebrates and what they can teach us about our ecosystems. Since then, he has been active in monitoring and assessing ecosystems for the past 25 years. When not working, Eric keeps visiting the mountains and coasts with his family, sometimes rock climbing or running as well. *eric_dinger@nps.gov