Sea Stars In Peril

Since the summer of 2013, millions of sea stars have died along the west coast of North America, but are scientists any closer to finding the cause? Dr. Ian Hewson answers our questions...

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The remains of sunflower stars in British Columbia, 2013. A gooey white mess, where once BC's iconic looking sea stars once flourished

September 19th, 2013

After hearing alarming reports of sunflower stars "losing their rays, rotting and turning into puddles of goo," biologist Doug Swanston and I headed out to northern Howe Sound, British Columbia to have a look for ourselves. This is a site where over the previously few years we had observed a very substantial population of these dinner plate-size stars, with densities of up to a dozen or more per square yard/metre.

As we dropped below a murky surface layer, the carnage before us on the steep rocky slope was beyond shocking. Hundreds upon hundreds of sunflower stars were in various stages of dying and death; some so weak they were literally tumbling down the slope, others whole but emaciated, still others shedding rays and with their internal organs protruding through ugly lesions. Hundreds of dead ones lay in rotting piles at the base of the cliff. We swam about 500 feet (150m) along the rocky wall and the gruesome situation hardly varied. Within that relatively small area we later estimated that more than five thousand sunflower stars were dying or already dead.

October 9th, 2013

Doug and I ventured to the north end of Indian Arm, BC, a narrow fjord just east of downtown Vancouver. We had previously encountered very large numbers of sunflower stars at this site too, and were anxious to see how they were faring. On the steep rocky slopes we found lots of sunflower stars with early signs of disease (looking weak and limp) but others that still appeared healthy. There were also thousands of young sunflower stars only two inches (5cm) across crawling amongst the adults. Several morning sun stars and mottled stars appeared to be dying, with white lesions forming on their bodies. Leather stars were very abundant but we did not see any with obvious signs of disease. We documented the scene with video and collected some specimens for analysis by the Pacific Biological Station Aquatic Animal Health Section in Nanaimo.

> *"All that remained were rotting bits and pieces and heaps of white bacteria at the base of the rock walls"*

October 29th, 2013

Twenty days later, when we made a return visit, it was hard to believe we were diving at the same site. Virtually every single sunflower star was gone. All that remained were rotting bits and pieces and heaps of white bacteria at the base of the rock walls. The morning sun stars were gone too, and while many mottled stars were sick, there were some that seemed unaffected. As before, the leather stars appeared unscathed.

Since those disturbing dives in Howe Sound and Indian Arm in late 2013, we dived at dozens of locations along the BC coast and the story was essentially the same: sea stars dying in incalculable numbers. It soon became clear that many different types of stars were impacted; of 30 shallow-water species, more than 20 were affected. And the disease wasn't just confined to BC waters; reports of dying stars were coming in from all over the west coast, from Alaska to Baja California, making it one of the largest recorded marine epidemics ever.

At first scientists were at a loss to explain what was happening. Initial lab studies did not reveal any obvious pathogen. Fortunately, the epidemic, dubbed the Sea Star Wasting Disease (SSWD), got the attention of Dr. Ian Hewson, an Associate Professor of Microbiology at Cornell University in New York. With the help of researchers and citizen scientists on the west coast, he and his team obtained samples of infected stars and got to work.

In a recent interview with DIVER, Ian explained how he got involved and what was learned about SSWD.

DIVER: When did first hear of this outbreak of SSWD? Why did you decide it was important to study it?

Ian Hewson: I was first made aware of the current SSWD event in August 2013. Emails started to trickle in from concerned divers, then aquariums and other researchers. Initially the disease event appeared to mimic previous die-offs of sea stars that occurred because of low oxygen conditions, but it became pretty clear that the same disease signs were present in geographically distant areas. It also appeared that it was moving from area to adjacent areas, which suggested some kind of pathogen.

The story of how I became involved is really a case of being in the right place at the right time. I'd just had the first publication ever describing viruses in any echinoderm accepted into the Journal of General Virology. We had surveyed viruses in Hawaiian urchins that had been sampled during a field class some months before. There, we'd found an interesting group of viruses (the densoviruses) that we'd never seen in any other marine invertebrate group. I was joking with fellow Cornell scientist Drew Harvell, who for years had been investigating die-offs of various marine invertebrates as part of her Research Coordination Network, that it would be great if there was a mass mortality of sea stars on which we could apply our approach. I guess I need to be careful what I wish for.

Shortly after hearing about the disease event I (and collaborator Ben Miner of the Western Washington University, Bellingham) approached the National Science Foundation for what's known as Rapid Response funding. They generously funded our work, which was to examine viruses, bacteria and other potential pathogens associated with the disease. We also obtained some funding from the Atkinson Center for Sustainable Futures at Cornell.

Dr Ian Hewson Associate Professor of Microbiology at Cornell University in New York

DIVER: Describe how you determined the identity of the pathogen.

IH: Our first effort to understand what might be involved in this disease was to look by microscopy and compare healthy to diseased tissues. This was done by histopathologist and veterinarian Alisa Newton at the Wildlife

Conservation Society. There really wasn't anything cellular that could be seen, although sometimes small cells, like bacteria, and always viruses, elude observation using this approach.

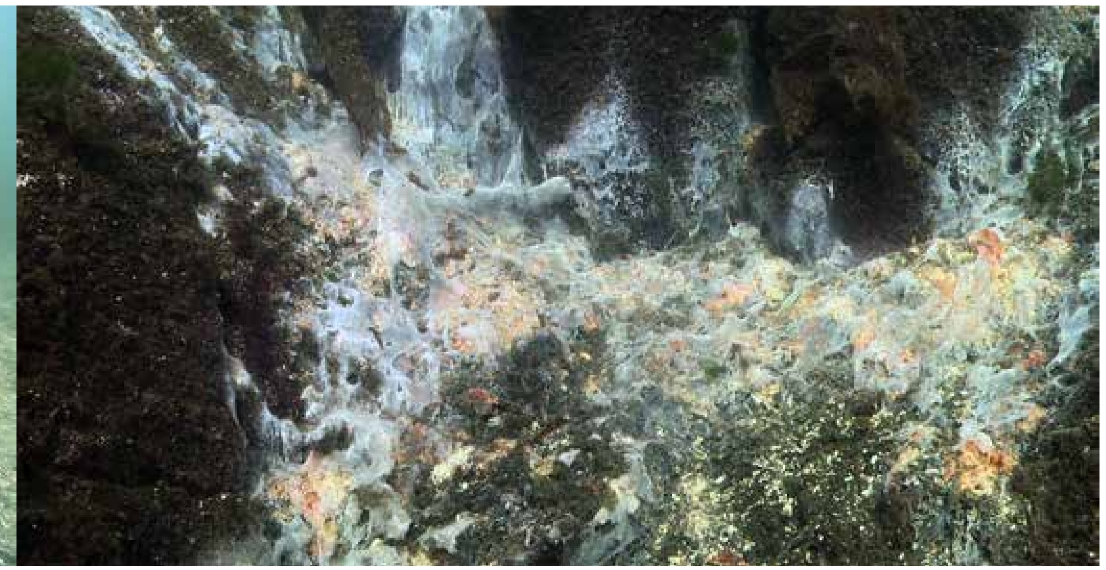
We next compared bacterial and viral communities between healthy and diseased tissues using molecular tools (i.e. those using DNA). This is necessary since most bacteria and viruses look similar based on morphology. Based on these comparisons, we identified a single virus, known as the sea star associated densovirus (SSaDV) as being primarily found in diseased tissues, but at the time there appeared not to be any other bacteria or viruses mostly associated with the disease.

From here, we wanted to test whether viruses (including SSaDV) could induce disease signs similar to SSWD. To do this, graduate student Morgan Eisenlord and postdoc Colleen Burge performed what are known as "challenge experiments," whereby healthy individuals (in this case, sunflower stars) were collected from the field, then injected with virus-sized material collected from diseased animals. After injection, the animals were observed for 14 days. During this time animals receiving live viruses from SSWD-affected stars became sick with the same symptoms as observed in the field, while controls – which received a heat attenuated portion of the viruses – did not. We looked at the pattern of viral abundance in tissues during this experiment and it was SSaDV that increased dramatically during disease progression. The experiment was repeated using viruses from animals that became sick from the first experiment, with the same effect. Hence, we can say that virus-sized particles cause SSWD and that SSaDV is the prime candidate of these viruses. What's less certain is how the viruses elicit the symptoms seen in the field or during experiments.

DIVER: SSWD is not a new phenomenon. There have been occurrences on the west coast from the 70s but this is by far the biggest, most deadly outbreak of all. The entire west coast from Alaska to Baja California has been impacted. What does that tell us?

IH: It tells us that there is something different about the current disease event. It could be that the pathogen (which we suspect is SSaDV) is somehow much more virulent than it may have been in the past. We have detected SSaDV-like densoviruses in historical specimens from decades ago, but they appear to be genetically different based on some recent work. Another possibility is that the animals have high densities (which could be due to decadal cycles of productivity, as an example) and therefore facilitate pathogen transmission much more easily than if they were rare. It is also possible that co-infection with another pathogen (which we haven't yet discovered) made the disease worse in this case. Finally, the oceans are changing as they heat up and absorb more carbon dioxide. It's possible that this makes the animals' condition poorer, which means they are more likely to get sick. However, we haven't yet figured out the right cocktail of environmental parameters that may have led to this worsening.

Top: Croker rock outcrop, October 9th, 2013. Above: The exact same location October 29th, 2013



Top: Sunflower sea star showing signs of withering. Above: The white "puddles of goo" divers were seeing all over the Pacific Northwest

> *"It could be that the pathogen is somehow much more virulent than it may have been in the past"*

DIVER: In BC, we had been seeing very high numbers of sunflower stars in certain areas, such as Howe Sound and Indian Arm. When SSWD struck in September 2013, these populations were wiped out in only a few weeks. Do you think the high densities contributed to the spread of the disease?

IH: It is entirely possible. Viruses, like most pathogens, have to move between animals in order to cause an infection. In the case of SSaDV, we've done experiments that show that it does not last long as a free virus particle, especially in sunlight. Hence, it's more likely that it moves around by contact between animals. If densities were as high as they were prior to 2013, it could greatly facilitate the spread of infection. But there are some mysteries here too: How did it move from place to place when there aren't continuous sea star populations? How did it effectively jump from the Pacific Northwest to Central California and bypass the coast in between? I think we have to look at either a secondary host, such as some kind of plankton, or perhaps spread in animal spawn.

DIVER: At other sites, such as in Sechelt Inlet, sunflower stars had never occurred in high densities, yet they all died nevertheless. How much of a viral load does it take to kill a sunflower star? Could a single viral particle be enough?

IH: This is an excellent question, and points to the fact that there may be a secondary host, or some kind of vector. We know that SSaDV doesn't survive long in the plankton, which means it has to hitch a ride on something else to infect stars that are far apart. A single virus particle may be enough to produce an infection, but that same virus particle, if free in the water column, has to make it past degradative enzymes produced by other organisms, contacting non-sea star organisms, including plankton, in order to finally find its host. Viruses generally decay rapidly in marine habitats; 2 to 4% per hour.

DIVER: At first it seemed that sunflower stars and purple stars were the main victims of SSWD but as time progressed, we started to find specimens of virtually every west coast sea star species with SSWD. The only species that seemed to tough it out was the leather star. Any idea why?

IH: This is another mystery. The sunflower, purple and mottled stars belong to a family of sea stars known as the Asteriidae. Bat stars, vermillion and velcro stars are in different families. It's unclear why leather stars may escape the disease. It is possible that they are already infected with a close relative to SSaDV which prevents them being infected by the potential disease-causing strain of SSaDV. But really, there are many different possibilities which we're currently considering.

DIVER: In areas where large numbers of sunflower stars died in Howe Sound and Indian Arm, their rotting bodies piled up in the thousands at the base of rocky cliffs. Is there now a huge reservoir of virus particles in those sediments?

IH: We have been able to detect SSaDV in sediments in the bottom of aquariums where animals once died, sometimes months after they disappeared. Similarly, we have found the virus in sediments next to decaying stars in the field. However, it's a bit unclear how fast they decay under natural conditions within sediments. Certainly we can recover things like viruses or cyanobacteria from very deep sediments which mean that they are several hundred years old. However, these are unique situations where muds are totally anoxic and many of the enzymes which degrade viruses are inhibited. I suspect that SSaDV doesn't last long in most sediments. Earlier this year we surveyed 19 sites in Puget Sound at depths of 100 to 165 feet (30 to 50m), and we couldn't detect SSaDV anywhere in the sediments.

DIVER: I was struck by the speed of death. In only 20 days the population at Indian Arm went from thousands of sunflower stars to zero. Is this swift progression of the disease unusual for a virus?

IH: It certainly can be, and I suspect it's something about the biology of echinoderms in general that facilitates their rapid decay. Sea stars, like all echinoderms, contain very large bacterial communities on their tissues and within their body cavities. When there is an upset to the animal, such as lower oxygen conditions, these bacteria become incredibly abundant and degrade their host, while under normal conditions they're kept in check by a series of immune defenses. We don't yet have a good handle on the time between primary infection and animal mortality, but in sunflower stars, which are less structural (they're more jelly-like), it's probably pretty quick.

DIVER: We are coming up on three years since the devastating outbreak in September 2013 and yet we are not seeing any substantive recovery of sunflower stars. Any idea why?

IH: Echinoderms in general are a boom-bust phylum experiencing massive changes in their abundance. Sometimes they boom – like what is happening to the crown of thorns on the Great Barrier Reef – and sometimes they die off spectacularly like what we have seen. This can lead to shifts in the dominant taxa. The niches previously occupied by one species move to another. In Southern California, almost all of the sun stars (Heliaster) disappeared during an El Nino event in the late 1970s. They haven't returned. It's quite possible that it will take decades for the west coast sunflower stars to return, if at all. But they are most definitely not extinct; during a recent survey at random sites in Puget Sound, we came across several large specimens of healthy sunflower stars. They're out there, but may not be present at the popular dive sites.

DIVER: You have determined the culprit in this disease outbreak yet we still don't know what triggered the virulence and scope of this event. Could climate change be at least part of the reason?

IH: We haven't yet determined the culprit in its entirety. We have a pretty strong candidate, but there are quite a few missing links which we're investigating at the moment, including other types of viruses and bacteria which on their own do not appear related to the disease but may be involved when co-infecting the same host.

Climate change is most definitely having severe repercussions for marine life, but we do not have a clear picture on how it may be involved in this disease, if at all. In experimental settings, large swings of temperature can cause SSWD-like symptoms. But in the field the disease gets worse and spreads more widely in the winter. Upwelling of low pH water also corresponds with the disease onset on some coasts. The spring-time temperature in Puget Sound earlier this year was the highest it's been in the last decade. Yet, the disease is waning with very few new reports. Untangling natural seasonal variation, or co-variation between the seasonal biology of the animals and physical/chemical changes is proving quite the challenge!

DIVER: Based on the mostly discouraging reports about the recovery of these sea stars, do you think this might be the new reality?

Sunflower stars - once a guaranteed dive sight, anywhere on the coast

"It really isn't in the best interest of viruses to kill of their hosts in their entirety – that's how they replicate!"

IH: I think in terms of populations, we'll see a shift in the composition of sea stars which may perhaps last for decades – it's hard to know. I think also that people, particularly those who explore the marine realm through intertidalling, snorkelling and diving, are more aware of disease events like this, so we will probably see more disease. Diseases of marine animals probably have been around since the first multi-cellular organisms swam in the oceans.

DIVER: What is the prognosis for recovery? Will the surviving stars develop immunity or will the virus mutate to become even more virulent?

IH: Hosts generally develop some kind of resistance to a pathogen during a disease event, so it's quite possible the surviving stars represent those that are not susceptible to the virus. Similarly, those millions of juveniles reported from the Pacific coast could be immune to the virus. It really isn't in the best interest of viruses to kill off their hosts in their entirety – that's how they replicate! Hence, we'll probably see SSaDV become less virulent in the future.

DIVER: Is this a new foreign invader or a resident virus that has suddenly gone rogue? Why did this virus become so virulent so fast and absolutely?

IH: This is a really big question, and one which we're trying to get a handle on through comparative genomics across sea stars from many locations worldwide. Most recently we've recovered SSaDV-like densoviruses from several other locations globally which have reported the disease. But none of these are totally identical, so it's unclear whether they are a source of viruses. Likewise through time it appears that SSaDV-like densoviruses have been present on the west coast, but it's really unclear how the disease-associated SSaDV strain has become so widespread and potentially virulent.

DIVER: First sea stars, now diseased sea cucumbers are showing up off the BC coast. Is there any connection?

IH: We've been hearing reports of some disease in sea cucumbers in coastal BC and indeed up into Alaska. However, our work to date hasn't identified any potential culprit. The only type of virus we seem to find in these animals is known as a circovirus, but we haven't found any association with the viral abundance and the animal disease. However, work continues in the lab to see how other potential pathogens, like other types of viruses or bacteria, may be involved.

Top: Covering Defence Island, 2010. Above: Urchin hordes take prominence, Jervis Inlet

The future

In the three years since Doug and I first observed that appalling outbreak of SSWD in British Columbia, the situation along the west coast seems to have stabilized. There are fewer reports of dying sea stars and even some signs of recovery. But the ecology of marine habitats has been drastically altered. In Sechelt Inlet (Sunshine Coast, BC), for example, where once dozens of voracious three-foot-wide (1m) sunflower stars roamed the rocky reefs, it's now rare to find even a single juvenile. Likewise for the morning sun star, a species that preyed extensively on sunflower stars. They too are gone. In the absence of predatory sea stars we've found unprecedented hordes of green urchins marching over the reefs, consuming virtually everything in their path. The long-term effects of their unchecked grazing are hard to predict, but could impact many species, such as juvenile rockfish, shrimp and two-spot prawns, which require broadleaf and bull kelps for shelter from predators.

It's hard to say what these reefs will look like five or 10 years down the road, so divers and other citizen scientists should continue to do their bit; observing, photographing and reporting any evidence of dying stars and signs of recovery. Let's hope this devastating disease has run its course and that we'll once again encounter our iconic sunflower stars and myriad others roaming the reefs of the west coast. [ ]

For more information about sea stars and SSWD including maps, pictures and forms for reporting observations, visit:

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