Red Tide

Devastates South African Abalone Farms

Dr. Anna Mouton, BVSc, MSc

South African abalone farms suffered devastating losses due to a harmful algal bloom earlier this year. Three farms situated in Hermanus, on the South coast, lost up to 50 percent of their stock. These farms held an estimated 24 million abalone, or a third of the total South African farmed abalone population.

"Worst South African Abalone Event in History"

The first mortalities occurred over the weekend of 14 and 15 January 2017. South African abalone farms are almost all situated on land. Continuous pumping from the sea maintains water quality in the abalone tanks under normal conditions. In the second week of January, the incoming water included harmful algae and their toxins.

After the initial deaths, the bloom remained offshore for several days and farmers hoped that the worst was over. Losses had been less than 10 percent. Surviving abalone were weak and some had bloated, but all appeared to be recovering. It was the calm before the storm.

As January transitioned to February, the bloom came onshore, this time to stay. Soon, staff on abalone farms were unable to keep up with removing dead animals. Some farms had people on site 24 hours a day and monitored incoming water hourly. The only available management option was limiting water intake at times of high algal density.

The affected farms are all in Hermanus, a small town in the Western Cape. Hermanus lies in Walker Bay, as does Gansbaai, another significant abalone farming town. The bloom extended as far as Gansbaai and then stretched beyond, to threaten farms at Buffelsjachts. Panic spread through the industry as people studied satellite images of the evolving bloom.

Gansbaai and Buffelsjachts were spared. The harmful phytoplankton did not come onshore in these localities. By the end of February, the bloom was no longer dominated by toxic species. Hermanus farms could begin to assess the damage. In all, they lost between 40 and 50 percent of their animals. This includes irreplaceable brood stock.

Tim Hedges, the managing director of Abagold, called the red tide the "worst South African abalone event in history." Abagold, the largest of the affected farms, later announced that it would not be declaring interim dividends.

Dynamics of South Coast Algal Blooms

Walker Bay is the epicenter of South African abalone farming. It lies close to the southernmost extent of the Benguela Current upwelling system. The region has weaker upwelling than the West coast, reducing the scale of harmful algal blooms. This has contributed to the success of abalone farming in the area, at least until now.

The upwelling of nutrients during summer fuels the development of phytoplankton blooms. Upwelling is driven by wind. In spring, diatoms often dominate whereas dinoflagellates become more prevalent in summer and autumn. Dinoflagellates are better adapted to stratified water and favored by relaxation of upwelling conditions.

Phytoplankton monitoring showed that the dominant species in Novem-

ber 2016 were in the genus *Pseudo-nitzschia*. Counts were in the tens of thousands of cells per liter, occasionally spiking to hundreds of thousands. Pseudo-nitzschia are chain-forming diatoms. During December, counts of *Pseudo-nitzschia* declined and the assemblage became more diverse, including several dinoflagellate species. *Gonyaulax spinifera* began to emerge as the front-runner, although cell counts were only in the low thousands per liter.

On 16 January 2017, *G. spinifera* was present at densities of 1.4 million cells per liter. It was a Monday. Abalone farmers arrived at work to find the first mortalities.

G. spinifera kills with yessotoxin

Dinoflagellates in the family *Gonyaulacaceae* produce yessotoxin. Problem species are *Protoceratium reticulatum, Lingulodinium polyedrum* and *G. spinifera*. Yessotoxin has long been a headache for shellfish farmers as it results in false positives for diarrhetic shellfish poisoning toxin on some tests. Most countries regulate the levels of yessotoxin in shellfish, even though there are no documented cases of toxicity in humans.

Research has suggested that certain strains of *G. spinifera* are more toxic than others. A study on two strains from the Adriatic Sea showed that they differed in gene sequence and toxin production. The more toxic strain produced a bloom that led to widespread closure of mussel farms. It formed primarily homoyessotoxin, an analogue of yessotoxin, whereas the less toxic strain contained only yessotoxin. The scientists compared the Adriatic Sea strains with a toxic strain from New Zealand. They con-

cluded that the more toxic Adriatic Sea strain was genetically closer to the New Zealand strain than to the less toxic Adriatic Sea strain.

Variability within *G. spinifera* may explain why this species did not impact on South coast abalone farms in the past. Yessotoxin had been detected in a handful of samples over the past decade, but at low levels. No one observed adverse effects in their stock.

In late January 2017, at the height of the red tide, a concentrated filtrate of the bloom was tested for yessotoxin by liquid chromatography–mass spectrometry (LC-MS). It contained 32.7 parts per million (ppm) of yessotoxin, of which 23.5 ppm was in the homoyessotoxin form. This toxin profile mirrors that found for toxic strains from New Zealand and the Adriatic Sea. In comparison, tissue levels in abalone showing clinical signs of toxicity were only 0.2 ppm.

Mortalities during blooms are often ascribed to depletion of dissolved oxygen. This was not the case during the South African event. Dissolved oxygen remained normal on affected farms. Histological examination of moribund and fresh dead abalone showed no evidence of algal cells clogging the gills.

New insights into yessotoxin pathology in abalone

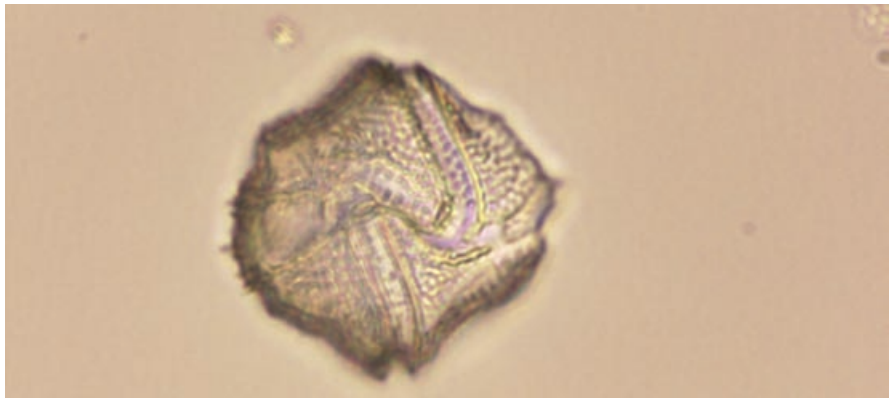
The effects of yessotoxin have been studied in the ever-unfortunate mouse. It is toxic when injected, but considerable research has not provided a satisfactory explanation of the cause of death. Oral administration does not cause poisoning, because yessotoxin is poorly absorbed from the gut. This may be the reason why there have been no human cases of yessotoxicity.

Extensive work on yessotoxin in cell cultures has yielded greater insights. Yessotoxin affects elements of the cytoskeleton, notably F-actin and E-cadherin. E-cadherin is highly conserved throughout the animal kingdom and thus likely to occur in abalone. Cadherins are important in cell adhesion and E-cadherin occurs in epithelial tissues. Abalone affected by the red tide showed significant disruption of the integrity of gill and external epithelia. This is consistent with loss of cell adhesion.

Yessotoxin also causes a type of cell death called apoptosis. One way in which it does this is by activating caspase proteins, particularly caspase 8. Abalone have caspase 8 and would be susceptible to cell death from yessotoxin exposure. It is not possible to differentiate apoptosis from other causes of cell death on histology. Cell death was widespread in the gills of abalone during the recent bloom and it is likely that yessotoxin exposure is responsible.

Weakness was one of the clinical signs during the red tide. A modest effect of yessotoxin on the function of calcium channels has been shown in mussels. Calcium plays a very important role in muscle function of gastropods and it is possible that yessotoxin may impair movement or grip.

Yessotoxin impacts the function of immune cells in mussels, but there was no evidence of this in abalone. Histology showed rapid development of bacterial and ciliate infections in animals that survived the initial toxicity. This evoked a vigorous inflammatory response and most individuals seemed able to clear the infections within several days to a week.



The speed at which survivors recovered was remarkable. Abalone sampled two to three weeks after exposure had normal gill epithelium. Active regeneration of epithelium was visible in the mantle cavity and on external body surfaces. The long term cost to performance is not yet known.

An anxious look to the future

Harmful algal blooms are a fact of aquaculture in a warming world. The first two months of 2016 saw *Pseudochattonella marina* kill an estimated 100,000 metric tons of salmon in Chile. A red tide of *Alexandria catenella* followed, causing mass mortalities in wildlife. There were protests by fishermen, who blamed the red tide on the salmon industry. Research suggests that El Niño was the real culprit.

In South Africa, phytoplankton counts have subsided with the onset of winter. The blooms will gather again in spring, but it is impossible to predict the dominant species. *Gonyaulax spinifera* has resting cysts and some of these will germinate in coming years. Research indicates that cyst density and germination rates are not predictive of bloom dominance.

Dr. Grant Pitcher has spent his career studying the dynamics of harmful algal blooms on the South African coast and around the world. His paper on mass mortalities of marine life caused by a *Gonyualax polygramma* bloom on the South coast in 2007 makes chilling reading. Pitcher thinks that the most unusual feature of the 2017 bloom is that *Gonyualax spinifera* came onshore in Hermanus. In Gansbaai and Buffelsjachts, the bloom remained offshore and did not affect the farms.

Abalone farms have a long production cycle and the impact of the red tide will reverberate for several more years. Support industries including processors and feed manufacturers will share the pain. There is a real fear that harmful algal blooms may become a regular feature in Hermanus. Farms are scrambling to find mitigation measures, well aware that more than survival of abalone may be at stake.

Dr. Anna Mouton.

Anna Mouton is a freelance writer and veterinarian. She has 20 years of experience in aquatic animal health. Her focus areas have been abalone culture and shellfish pathology. She can be contacted at anna@annamouton.com.