# Bringing White Abalone Back from the Brink

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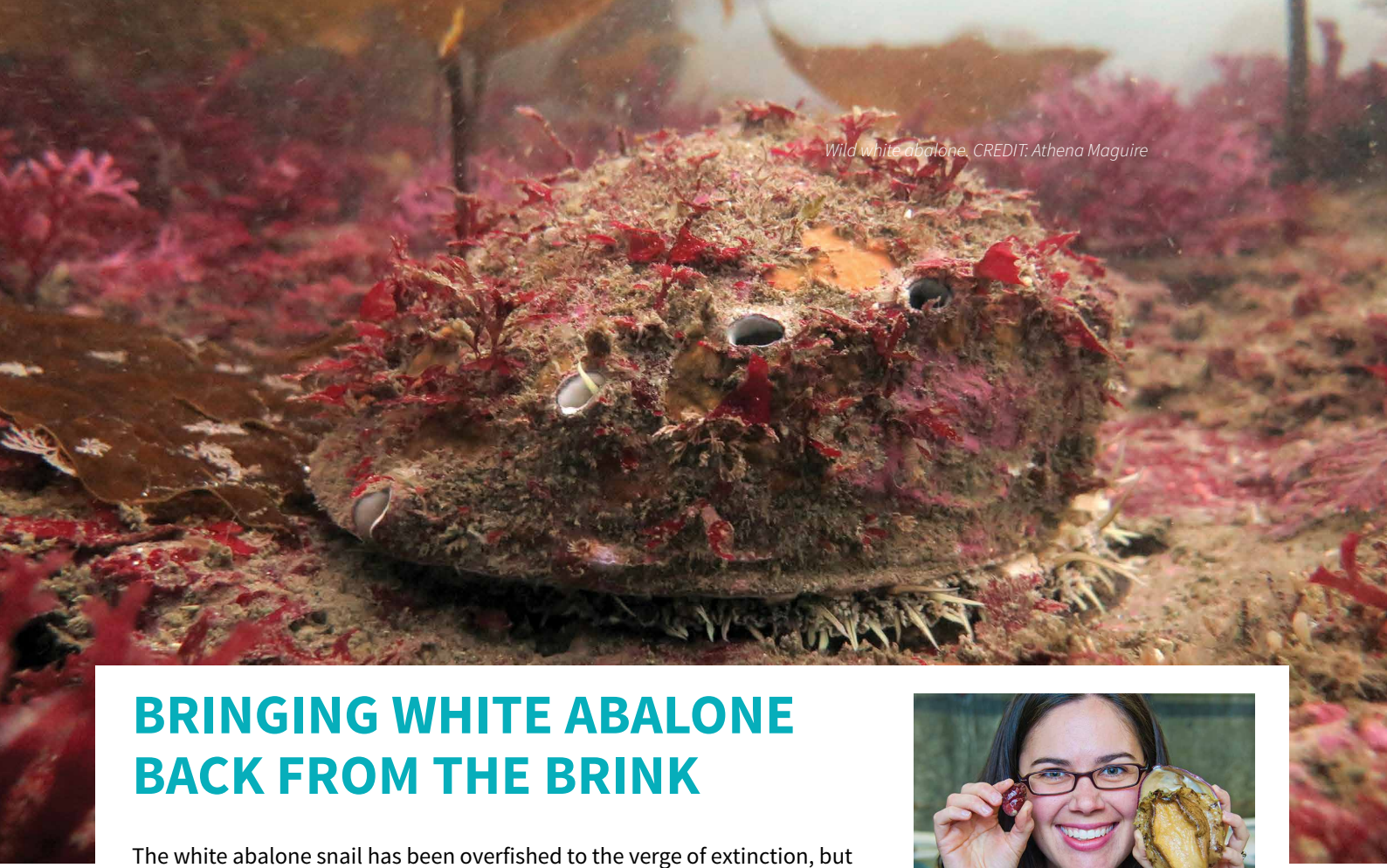
Scientia

CREDIT: Michael Ready



*Wild white abalone, CREDIT: Athena Maguire*

# BRINGING WHITE ABALONE BACK FROM THE BRINK

The white abalone snail has been overfished to the verge of extinction, but **Dr Kristin Aquilino and Professor Gary Cherr** at UC Davis hope to save the species by reintroducing their captive-bred population back into the wild.



*CREDIT: Sammy Tillery*

**Threatened by Overfishing**

Although trying to get sea snails in the mood for love might not be everyone's cup of tea, Dr Kristin Aquilino loves her job at the frontline of building up captive breeding populations of the endangered white abalone. 'I love the sense of purpose that comes with restoring an endangered species, advancing knowledge, promoting science and education, and supporting sustainable aquaculture,' she tells Scientia. The white abalone (Haliotis sorenseni) was once common in kelp forests off the coast of Southern California and Mexico, and has been harvested by humans for around 10,000 years. It plays an important role in the kelp forest ecosystem, competing with other algal grazers such as sea urchins and keeping their numbers under control.

Valued as a delicacy, white abalone also historically supported a fishery, making an important contribution to the local economy. However, ever-increasing demand, coupled with newer fishing techniques, led to intense overfishing in the 1970s. This pushed the white abalone to the edge of extinction in California. At its most abundant sites, white abalone numbers dropped by around 80% in eight years, from an estimated 15,000 in 2002 to 3,000 in 2010, and to less than 0.1% of its historical, baseline level. After some earlier conservation measures, white abalone fishing was finally banned in 1996. Despite this, in 2001, the species had the dubious honour of becoming the first invertebrate on the US federal endangered species list.

Although the white abalone is also found in Mexican waters, the status of its population there is unknown, and it is thought to be in significant decline. Even with the fishing ban in place, the US population has yet to show signs of turning the corner. Only one juvenile white abalone has been found in the wild in the last 30 years. One of the obstacles affecting the snail's recovery is that, for it to breed, males and females need to be within a few metres of each other. Only when they are close together can the eggs released by the females be fertilised by the sperm from the males – and with the low numbers left in the wild, spawning individuals are too far apart. Scientists agree that a captive breeding program is the only hope of survival for the white abalone, and without such efforts, it could be extinct within 20 years.

**Breeding White Abalone in Captivity**

At the White Abalone Culture Facility in the Bodega Marine Laboratory (University of California, Davis), Dr Aquilino and Professor Gary Cherr carry out research into the white abalone's reproductive biology, hoping to ultimately improve the survival of captive-bred snails in the wild. Professor Cherr, a reproductive biologist, explains why he finds this particular research project so rewarding, 'The endangered white abalone captive breeding program was an opportunity to apply my background and interest in reproductive biology to a conservation-oriented project with the goal of restoring a species which almost completely disappeared because of human beings.'

The Bodega team is part of the White Abalone Recovery Program, a consortium of partners working together to save the white

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*Juvenile white abalone. CREDIT: Joshua Asel*

abalone, with members from federal and state agencies, aquariums and the California aquaculture industry, as well as UC Davis and UC Santa Barbara. Thanks to funding from the NOAA National Marine Fisheries Service, their breeding program has experienced dramatic increases in success, producing 20 one-year-old abalone in 2012, 150 in 2013 and an impressive 10,000 in 2016. The captive population now almost certainly outnumbers the few remaining wild abalone.

The breeding program owes its success to the Bodega Marine Laboratory research team’s dedication to getting the conditions just right for each stage of the abalone’s complex reproductive cycle. Discussing the challenges, Professor Cherr says, ‘A single sperm cell must swim through treacherous waters to reach an egg, penetrate through the protective layers surrounding the female germ cell, and then successfully fertilise it. This is a truly remarkable feat and is a wonder of biology. For our work with the white abalone, we are trying to overcome all odds and not only enable high fertilisation rates for millions of eggs, but also for subsequent embryo development, larval hatching, and finally larval settlement and metamorphosis. This is not an easy task when every egg, embryo, and larva are as precious to the world, as they are with the white abalone.’

To get the captive abalone to breed, the scientists start by adding small amounts of hydrogen peroxide to the seawater, which introduces reactive oxygen species that encourage the abalone to spawn, releasing eggs and sperm. The team collects these and combines them in the best ratios for fertilisation. This produces embryos, which are transferred into a hatching container, and hatched larvae migrate into buckets through special tubes. When the larvae are old enough (~7 days), the team adds a biochemical signalling substance which induces them to settle on tiles covered with the small microalgae that they feed on. At around 5 months old, the juvenile abalone can be weaned on to larger leafy algae.

The White Abalone Recovery Program’s early breeding efforts were affected by outbreaks of a bacterial disease known as withering syndrome. The bacteria attack the abalone’s gut, preventing it from producing digestive enzymes, so it cannot feed and its muscle withers, and they may die. This killed almost all of the estimated 100,000 juvenile abalone produced in 2001 at a facility in Southern California. Dr James Moore (UC Davis School of Veterinary Medicine and California Department of Fish & Wildlife) has developed a strict hygiene regimen at all facilities. The abalone are kept in seawater which has been filtered and sterilised with ultraviolet radiation to kill the bacteria that can cause withering syndrome. For when new white abalone come into captivity, or in rare cases when captive white abalone contract the bacteria, the team has developed an antibiotic bath treatment that eliminates the bacteria. Controlling the temperature of the abalone’s seawater is also important, as this disease only occurs at higher temperatures. Another possible cause of abalone death is damage by organisms such as polychaete

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*Close up of eggs being spawned out of a newly-collected wild female. CREDIT: Michael Ready*

*Adult white abalone. CREDIT: Kristin Aquilino*

worms, which can bore through their shells. To keep their snails happy as clams, the team even wax the adults’ shells twice a year, protecting them from boring worms. ‘Between antibiotic cleansing baths and exfoliating, coconut oil and beeswax treatments, our white abalone healthcare plan now reads like a relaxing spa retreat,’ Dr Aquilino jokes.

**The Road to Recovery**

The program reached a special milestone in 2015, when it produced enough young abalone for Dr Aquilino, Professor Cherr and their team to distribute some to their partners. The main breeding program has now expanded to the small populations at five other institutions. Perhaps most exciting, the team is also making plans for how to reintroduce the white abalone into the wild. The Bodega Marine Laboratory scientists hope to transplant their first captive abalone within the next couple of years. To avoid risking the fragile captive white population, Dr Laura Rogers-Bennett’s team with the Bodega Marine Laboratory and the California Department of Fish and Wildlife are currently experimenting with a less threatened relative, the red abalone, to conduct outplanting trials. They are looking at ways to maximise the survival of their transplanted abalone, such as relocating sea stars and octopus from the reintroduction sites to reduce their predation of abalone, and stocking abalone in winter when some predators will be less abundant.

The team also hope to discover which sites offer the best conditions for abalone at different life stages, based on their understanding of these factors in captivity, and more research and monitoring of abalone and their preferred habitats in the wild. Some of their key questions include whether abalone prefer certain surface types, whether artificial reefs can provide suitable habitats, and which temperatures are most suitable. Dr Aquilino and Professor Cherr explain that it is also unknown whether sea currents and competition with other species affect wild abalone mortality, and whether environmental changes due to climate change will have an impact.

The team is keen to ensure that their captive population is as healthy as possible, so that they have better prospects of surviving their challenging transition to life in the wild. To that end, they would like to further refine their breeding and rearing techniques, to increase reproduction to minimise the mortality of young abalone. ‘We are looking forward to continuing to enhance our reproduction and rearing techniques through experiments aimed at understanding reproductive conditioning and survival during their early life stages,’ Dr Aquilino says.

One of the issues that concerns them about their captive breeding population is the possible negative effect of working with a relatively small number of individuals – low genetic diversity in the adults could lead to offspring with lower levels of fitness, and this becomes more likely with each generation of inbreeding. So the team applied for a special permit from the US National Oceanic and Atmospheric Administration, to allow them to take a small number of white abalone from the wild to supplement their breeding program. They were delighted to receive the permit in September 2016. The wild abalone they gather will introduce vital new genetic material into the captive population. One newly-collected female spawned in March 2017, marking the first time in 14 years that new genes had been added to the captive population.

The team also plans to use some exciting new techniques to increase the genetic diversity. ‘We have started to freeze (cryopreserve) sperm from a number of male white abalone and these frozen sperm cells can be stored for years but thawed as needed for fertilising eggs from females with different genetic backgrounds,’ Professor Cherr explains. ‘This can allow us to create genetic crosses that previously were not possible with the use of only fresh sperm. Our goal is to increase the efficiency of both in vitro fertilisation methods as well as embryo and larval culture techniques such that we can increase the percentage of juvenile white abalone in our breeding facility in Bodega Bay, CA. This will accelerate the timeline for our imminent release of young white abalone back into the field.’

Thanks to all the hard work of the Bodega Marine Laboratory research team and their partners, the white abalone could be one of the great success stories of conservation. Dr Aquilino is optimistic about the snail’s future: ‘By replacing overhead pipes with towering kelp forests and swapping out submersible pumps for steady ocean swells, we hope our precious baby snails might save their species from extinction.’

# Meet the researchers


**Dr Kristin M Aquilino**
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Dr Kristin Aquilino was awarded her BSc in Zoology at the University of Wisconsin in 2005, followed by her PhD in Population Biology at the University of California, Davis in 2011. She continued her work at UC Davis as a postdoctoral scholar from 2011 to 2013 in the Bodega Marine Laboratory, after which she worked at NOAA National Marine Fisheries Service as an independent contractor from 2013 to 2016. Since 2016, she has been Assistant Project Scientist at the UC Davis Bodega Marine Laboratory. She recently received the 'Species in the Spotlight Hero Award' from the US National Oceanic and Atmospheric Administration for her work trying to save white abalone.

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**Professor Gary Cherr**
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Professor Gary Cherr obtained his BA in Biology from Sonoma State University in 1979, and his PhD in Zoology from the University of California, Davis in 1984. From 1984 to 1986 he was a National Institutes of Health Postdoctoral Fellow at the UC Davis School of Medicine. In 1986 he joined the UC Davis Bodega Marine Laboratory, and in 1999 he became Professor in Environmental Toxicology and Nutrition at the Laboratory. He was Acting Director from 2007 to 2008, Interim Director from 2009–2015, and Director from 2016–present.

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## KEY COLLABORATORS

NOAA National Marine Fisheries Service
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The Cultured Abalone Farm

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