Photos for California marine life impacts of warming seas:

"Jellyfish such as these Northeast Pacific sea nettles in Monterey Bay Aquarium, are brainless, bloodless and mostly aimless." (John Lee/Aurora Select) from "Jellyfish: The Next King of the Sea", Smithsonian Magazine, August 2010

Species Name: Pacific Sea Nettle (*Chrysaora fuscescens)*
What it eats: Other jellies and zooplankton like fish eggs and snails
What eats it (predators): sea turtles, ocean sunfish (*Mola mola*) and Northern Fulmer seabird
Impact of warming ocean temperatures:

- population numbers are predicted to increase
- jellies can tolerate low oxygen levels so as the ocean warms up and oxygen levels drop scientists predict jellies may survive while other marine animals not as tolerant of lower levels of oxygen will die

Information from: "How are jellyfish connected to climate change?" Oct 29, 2019 Mark Ohman is a biological oceanographer and curator of the Pelagic Invertebrate Collection at Scripps Institution of Oceanography at UC San Diego.

https://scripps.ucsd.edu/news/voyager-how-are-jellyfish-connected-climate-change

Aquarium of the Pacific http://www.aquariumofpacific.org/onlinelearningcenter/species/pacific_sea_nettle

"Jellyfish: The Next King of the Sea", by Abigail Tucker, Smithsonian Magazine, August 2010
https://www.smithsonianmag.com/science-nature/jellyfish-the-next-king-of-the-sea-679915/

"Dead [California] mussels on the rocks in the Bodega Marine Reserve on June 19, 2019. (Photo by Jackie Sones, The Natural History of Bodega Head)

Species Name: California mussel (*Mytilus californianus)*
What It Eats: plankton that it filters from the ocean
What Eats It (predators): crabs, seabirds, starfish
Impact of warming ocean temperatures:

- mussels are getting too hot and are dying not only from increasing ocean temperatures but from increasing air temperatures as well.
- survival rate of mussels as ocean temperatures warm along the west coast seems to depend on their habitat. In some places like Washington, changes in air temperature will have a greater impact while in a place like southern California changes in water temperature are more likely to impact mussels.
- mussels are also struggling to build their calcium carbonate shells as the ocean becomes more acidic

Information from:

"California's June Heat Wave Cooked Mussels in Place" by Eric Simons, Bay Nature Magazine, June 26, 2019
https://baynature.org/2019/06/26/californias-early-june-heat-wave-cooked-coastal-mussels-in-place/

"Mussel strain: Same species responds differently to same warming depending on location" by Sandra Hines, University of Washington News, June 6, 2006
https://www.washington.edu/news/2006/06/06/mussel-strain-same-species-responds-differently-to-same-warming-depending-on-location

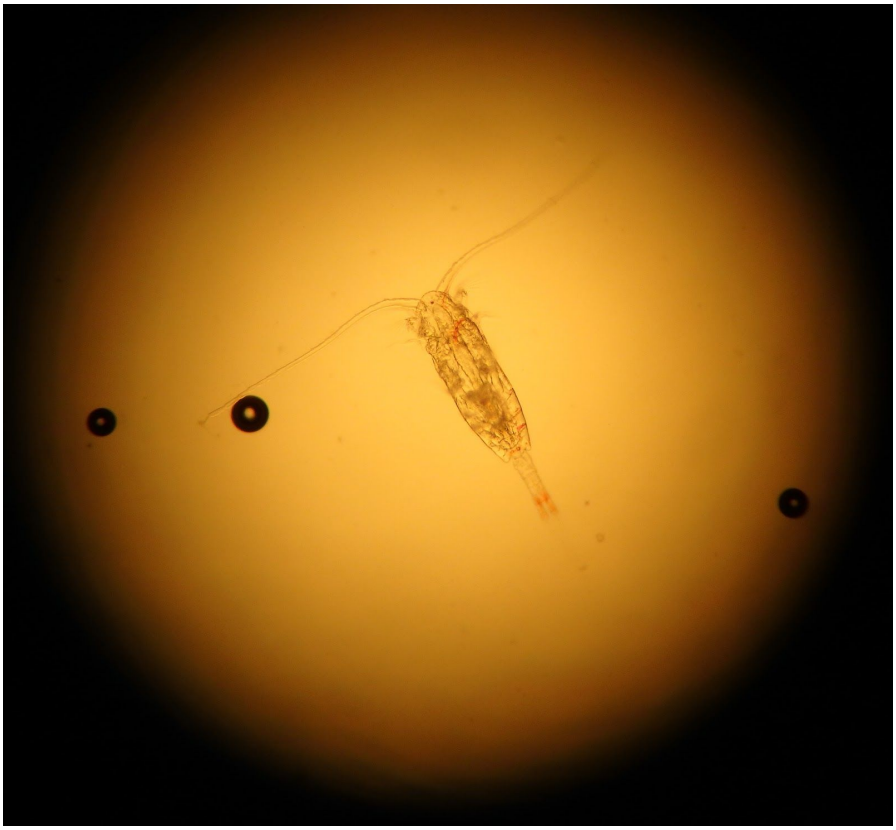
Nudibranch aka sea slug (*Phidiana hiltoni*) Photo by Bruce Wight from The Sea Slug Forum
http://www.seaslugforum.net/find/phidhilt

Species Name: Aeolid Nudibranch (*Phidiana hiltoni)*
What It Eats: hydroids (animals that look like jellies and are often in a colony) and attacks, and sometimes eats, other nudibranchs
What Eats It (predators): not much, occasionally crabs, sea spiders
Impact of warming ocean temperatures:

- Potential link between the warming ocean and the nudibranch *Phidiana hiltoni* being found further north than ever before. In 1977 this nudibranch was found north of Monterey Bay for the first time and continued to move north now in Bodega Bay. This 200km (125 miles) range expansion has continued as the oceans have continued to increase in temperature.
- As the *Phidiana hiltoni* has moved in, the population of other nudibranch species in the area has declined because the *Phidiana hiltoni* preys upon nudibranchs in the area and outcompetes the local species for food.
- Scientists suggest that the *Phidiana hiltoni* is changing food webs and the ecosystems “at sites along the California coast where its populations are dense.” (Jeffery Goddard, “2018 Report Indicators of Climate Change”)

Information from the Sea Slug Forum http://www.seaslugforum.net/find/phidhilt, Jeffrey Goddard via Office of Environmental Health Hazard Assessment, California Environmental Protection Agency (2018). Indicators of Climate Change in California. “2018 Report: Indicators of Climate Change in California” https://oehha.ca.gov/media/downloads/climate-change/report/2018caindicatorsreportmay2018.pdf

and King, Clara Jo; Ellingson, Ryan; Goddard, Jeffrey H. R.; Johnson, Rebecca F.; and Valdes, Angel A. (2019) "Range expansion or range shift? Population genetics and historic range data analyses of the predatory benthic sea slug Phidiana hiltoni (Mollusca, Gastropoda, Nudibranchia)," *Bulletin of the Southern California Academy of Sciences*: Vol. 118: Iss. 1. Available at: https://scholar.oxy.edu/scas/vol118/iss1/1



Antarctic Copepod Photo by Amy Osborne (PolarTREC 2019), Courtesy of ARCUS

Species Name: Copepod (***there are many species of copepods***)
What It Eats: phytoplankton
What Eats It (predators): small fish like anchovies, whales, seabirds
Impact of warming ocean temperatures:

- Decrease in more nutritious and larger cold water copepods and increase in less nutritious and smaller warm water copepods.
- Cold water copepods are essential food for pelagic (open ocean) fishes so fewer cold water copepods means less nutritious food for fish.

Information from Kym Jacobson and Jennifer Fisher via the Office of Environmental Health Hazard Assessment, California Environmental Protection Agency (2018). Indicators of Climate Change in California. “2018 Report: Indicators of Climate Change in California”
https://oehha.ca.gov/media/downloads/climate-change/report/2018caindicatorsreportmay2018.pdf

Chinook salmon Photo courtesy of NOAA (https://www.fisheries.noaa.gov/species/chinook-salmon)

Species Name: Chinook Salmon (*Oncorhynchus tshawytscha*)
What It Eats when young: insects, crustaceans, amphipods
What It Eats when older: other fish
What Eats It-predators: when young: fish and birds; marine mammals (orcas and sea lions) and sharks
Impact of warming ocean temperatures:

- salmon are born in freshwater and then make their way to the ocean to feed and grow then return to the freshwater place where they were born to spawn-lay their eggs. Scientists suggest that the warming freshwater temperatures will delay adults' migration into freshwater habitats to lay their eggs and could cause juvenile salmon to leave their freshwater habitat too early.
- Once they leave the freshwater habitat where they were born and swim out to sea young salmon depend upon food like krill, crab larvae and small fish.The increasing temperatures of the ocean could impact this food.
- Salmon depend upon ocean upwelling-a wind-driven motion of dense, cooler, and usually nutrient-rich water towards the surface- to bring their food to the surface of the ocean. As the oceans warm upwelling events are weakening so less nutrient-rich water is reaching the surface.
- Salmon are a top predator and prey that are integral to California's ocean food web.

Information from NOAA Fisheries Species Directory: Chinook Salmon https://www.fisheries.noaa.gov/species/chinook-salmon and Brian Wells via the Office of Environmental Health Hazard Assessment, California Environmental Protection Agency (2018). Indicators of Climate Change in California. "2018 Report: Indicators of Climate Change in California" https://oehha.ca.gov/media/downloads/climate-change/report/2018caindicatorsreportmay2018.pdf

California sea lion (*Zalophus californianus*) and a Western gull (*Larus occidentalis*) in La Jolla, San Diego, California. Photo by Rhododendrites, 7 October 2016 licensing through the Creative Commons Attribution-Share Alike 4.0 International

Species Name: California Sea Lion (*Zalophus californianus*)
What It Eats-prey: squid, octopus, small fish including herring, anchovies, and small sharks
What Eats It-predators: orcas, great white sharks
Impact of warming ocean temperatures:

- Sea lions will struggle to find nutritious food. They eat animals like small fish and squid. Small fish and squid find food in colder water that rises to the surface of the ocean through a process called upwelling-a wind-driven motion of dense, cooler, and usually nutrient-rich water towards the surface. As ocean temperatures warm upwelling weakens and the sea surface temperature increases. This increase in temperature and lack of cold nutrient-rich water reduces the amount of prey available for sea lions.
- Sea lion pups will become malnourished. When sea lions are born their mothers leave them along the coastline while they look for food. As prey decreases sea lion mothers must travel farther and use more energy to find food. Once sea lion pups learn to forage on their own they must also travel farther from shore and expend more energy to find food. If they haven't stored enough fat the pups can become malnourished.

Information from The Marine Mammal Center website https://www.marinemammalcenter.org/education/marine-mammal-information/pinnipeds/california-sea-lion/ and Sharon Melin via Office of Environmental Health Hazard Assessment, California Environmental Protection Agency (2018). Indicators of Climate Change in California. "2018 Report: Indicators of Climate Change in California" https://oehha.ca.gov/media/downloads/climate-change/report/2018caindicatorsreportmay2018.pdf

Story of an Antarctic Research Team

By Amy Osborne

(underlined sections have visuals that are attached)

You have been transported to the most southern continent on earth...Antarctica. As you look around it is mostly white. There are some snow covered mountains with dark rock peeking out. Then there is the sea that is covered in ice. A flat vast area of white ice where in warmer months you might see ocean.

You are joining Dr. Amy Moran and her team of researchers on an expedition across the sea ice. Dr. Moran and her team are excited to conduct research in Antarctica, especially since the ocean near McMurdo Station, Antarctica is a fairly constant temperature of -1.8°C. It is. also, somewhat isolated from the rest of the world's ocean water due to the Antarctic Circumpolar Current that keeps the water flowing in a clockwise direction around Antarctica.

You get into a red vehicle, called a Pisten Bully, with tracks, like a bulldozer or tank, that move it along the ice and thin layer of snow that covers the sea. As you bump along across the sea ice in the back of the vehicle you stare out the window at the blowing snow and red flags that mark the "road". After 45 minutes you make it to your destination... a blue and yellow one room small building with a hole in the floor known as the dive hut. You help the researchers and divers unload SCUBA tanks and bags filled with dry suits from the back of the vehicle. Dry suits will keep the divers dry when they are in the frigid water. Some of the divers even wear heated vests under their dry suits!

You take everything into the small building and try to stay out of the way as the divers put on their dry suits and all of their SCUBA gear. As they sit around the hole in the floor which leads through the sea ice to the ocean below, the divers talk about what they are collecting that day...marine ectotherms (animals that get their body temperature from their environment...also known as cold-blooded). They are specifically looking for sea spiders, nudibranchs also known as sea slugs, and any egg cases they can find.

Once all of the divers have jumped through the hole to the frigid waters below you and the other dive tender keep an eye on the water in the hole for any signs of bubbles meaning a diver is coming up. You also use your scientific equipment to measure oxygen levels, salinity, and temperature of the water, and heat up lunch for everyone on the small stove that is in the dive hut. When you see bubbles rising in the dive hole you

prepare to grab the divers fins and SCUBA tanks before they climb up the ladder out of the water.

Once the divers are out of the water they begin to pull up what they have collected...sea spiders-eight legged creatures that are brown and yellowish orange, some are about the size of the lid to a peanut butter jar, some males are carrying orange colored eggs- and nudibranchs-sea slugs that are white and look like fancy snails without a shell- and some sea slug egg cases that look like spiraled white string.

The collected animals are put into a large yellow cooler filled with ocean water. You all eat some lunch and the divers change out of their dry suits. The gear, animals, and people are loaded back into the Pisten Bully and you all bump your way back to the snow covered land and the aquarium where the animals will be stored and observed.

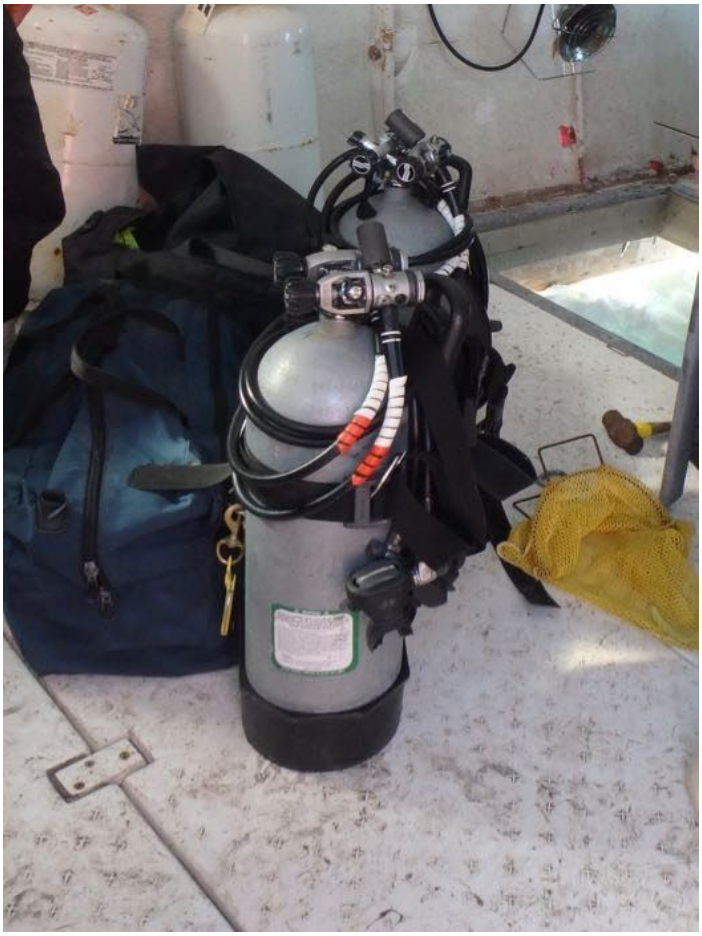
Photos for “Story of An Antarctic Research Team”

A sea covered in ice known as sea ice near McMurdo Station, Antarctica. Photo by Amy Osborne, courtesy of ARCUS

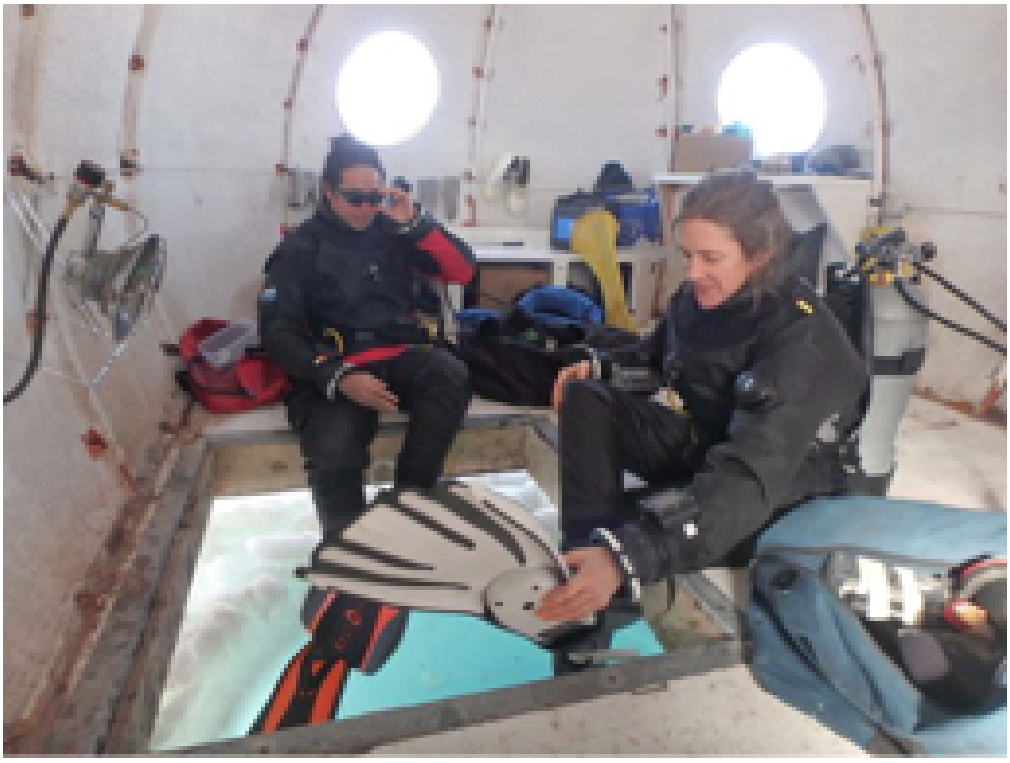
Pisten Bully on the sea ice near McMurdo Station, Antarctica. Photo by Amy Osborne courtesy of ARCUS

Driving along a sea ice “road” in Antarctica. Photo by Amy Osborne, courtesy of ARCUS

PolarTREC educator, Amy Osborne, enters a dive hut which has been placed on the sea ice near McMurdo Station, Antarctica. Photo by Denise Hardoy courtesy of ARCUS



SCUBA tanks that divers use to help them breathe when going underwater. Photo by Amy Osborne, Courtesy of ARCUS

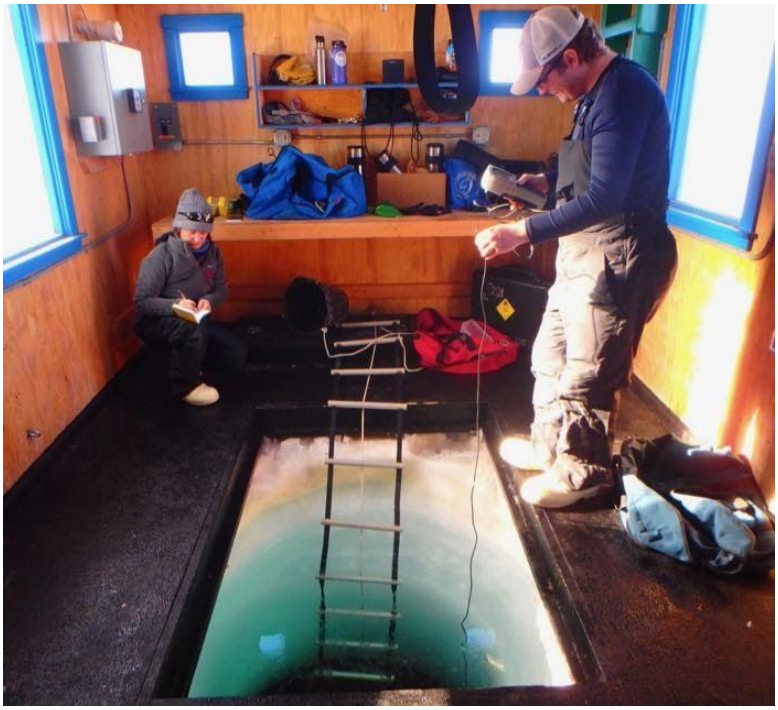


Dressed in dry suits, science divers and researchers Dr. Amy Moran and Aaron Toh prepare to dive through a hole in the ice into the frigid waters below. Photo by Amy Osborne courtesy of ARCUS

Nudibranch egg case. Photo by Amy Osborne, courtesy of ARCUS

Sea spider (*Ammothea*) with egg cases. Photo by Amy Osborne courtesy of ARCUS Crary Lab, McMurdo Station, Antarctica (2019)

Dive tender and PhD student Graham Lobert helps diver and PhD student Aaron Toh, dressed in a dry suit, with his collecting device and flashlight. Photo by Amy Osborne, courtesy of ARCUS



PolarTREC educator Amy Osborne and PhD student Graham Lobert take salinity, oxygen, and temperature measurements of the ocean. Inside a dive hut on the sea ice in Antarctica. Photo by Anne Todgham, courtesy of ARCUS

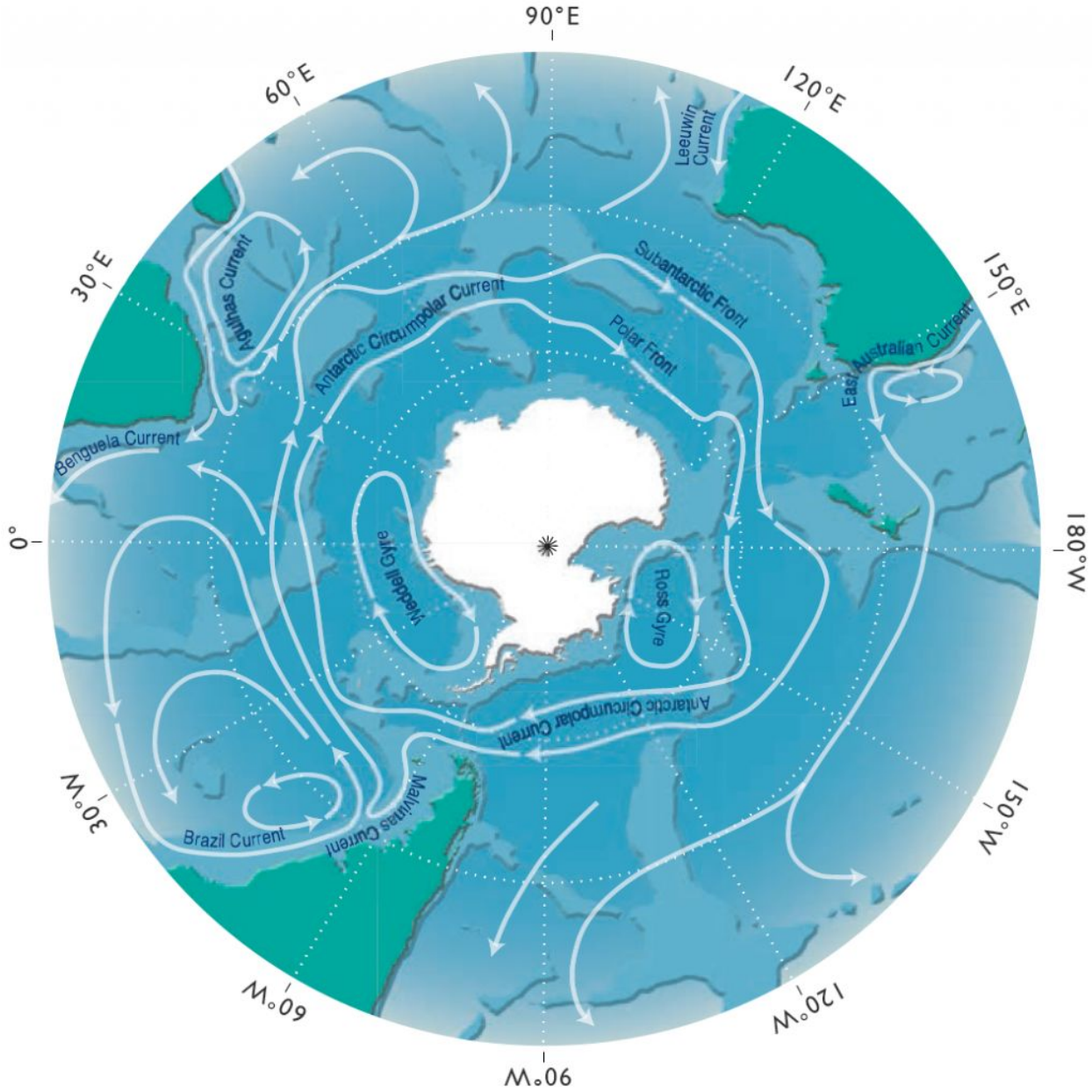
Researcher Dr. Amy Moran and Graham Lobert put sea spiders into a cooler of sea water to transport them back to the lab. Photo by Amy Osborne courtesy of ARCUS

PhD students Graham Lobert and Aaron Toh look at nudibranch eggs under a microscope and record what they are seeing. Crary Lab, McMurdo Station, Antarctica, Photo by Amy Osborne courtesy of ARCUS

Underwater in Antarctica, researcher and diver Dr. Amy Moran searches for and collects sea spiders, nudibranchs, and their eggs. Photo by Tim Dwyer, courtesy of ARCUS

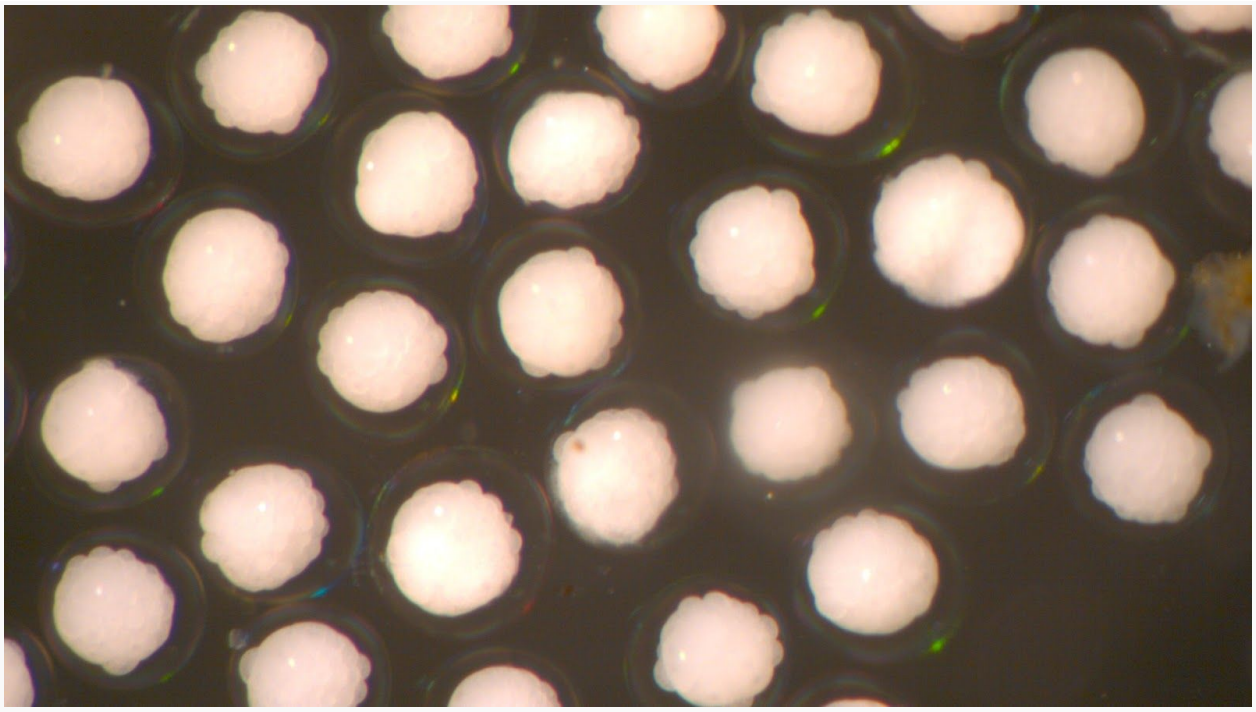
Adult nudibranch (*Tritonia challengeria*) Photo by Amy Osborne, Courtesy of ARCUS

Adult sea spider (*Ammothea*) Photo courtesy of ARCUS by Amy Osborne, Crary Lab, McMurdo Station, Antarctica (2019)

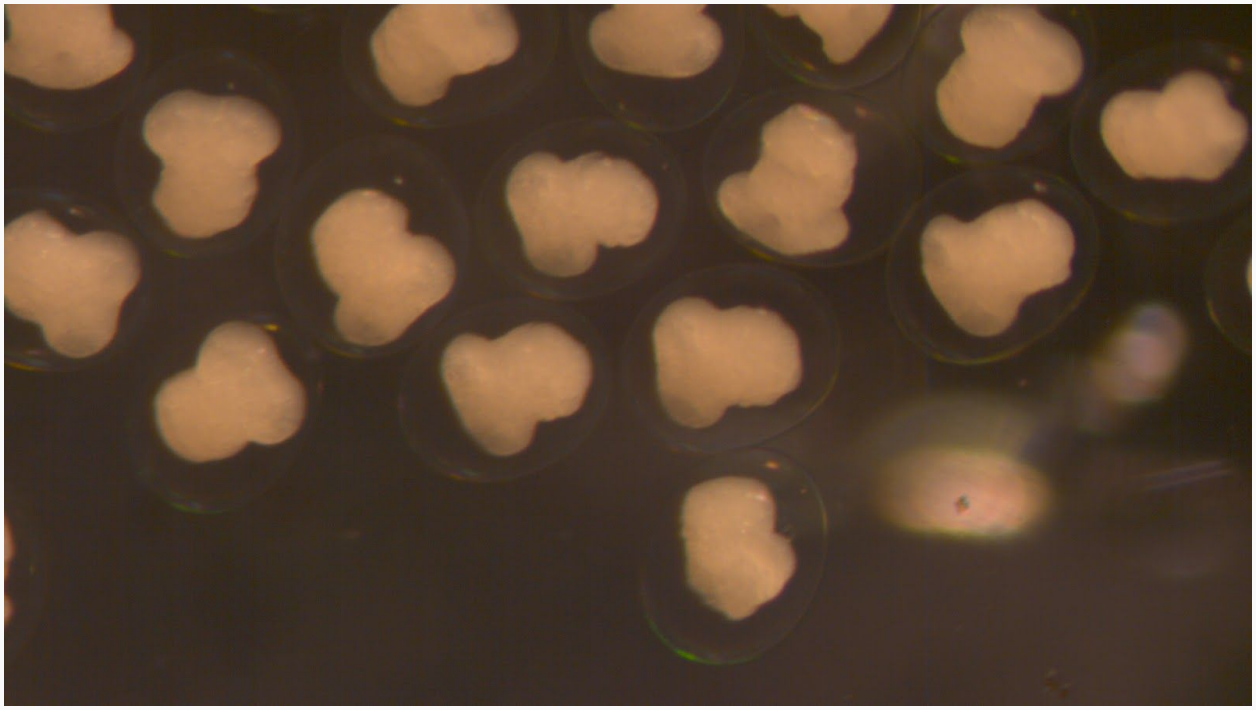


"The major ocean currents south of 20°S are shown by the arrows. The largest current in the world, the Antarctic Circumpolar Current, circles from west to east around Antarctica. This current creates a fairly isolated marine ecosystem in the ocean around Antarctica. As a result, warm subtropical waters are kept away from the continent and the ocean temperature in the Southern Ocean is fairly constant. Around McMurdo Station the ocean temperature stays constant at around -1.8°C" (Diagram courtesy of Academic Press / de Vos Design) (Photo: Academic Press / de Vos Design)

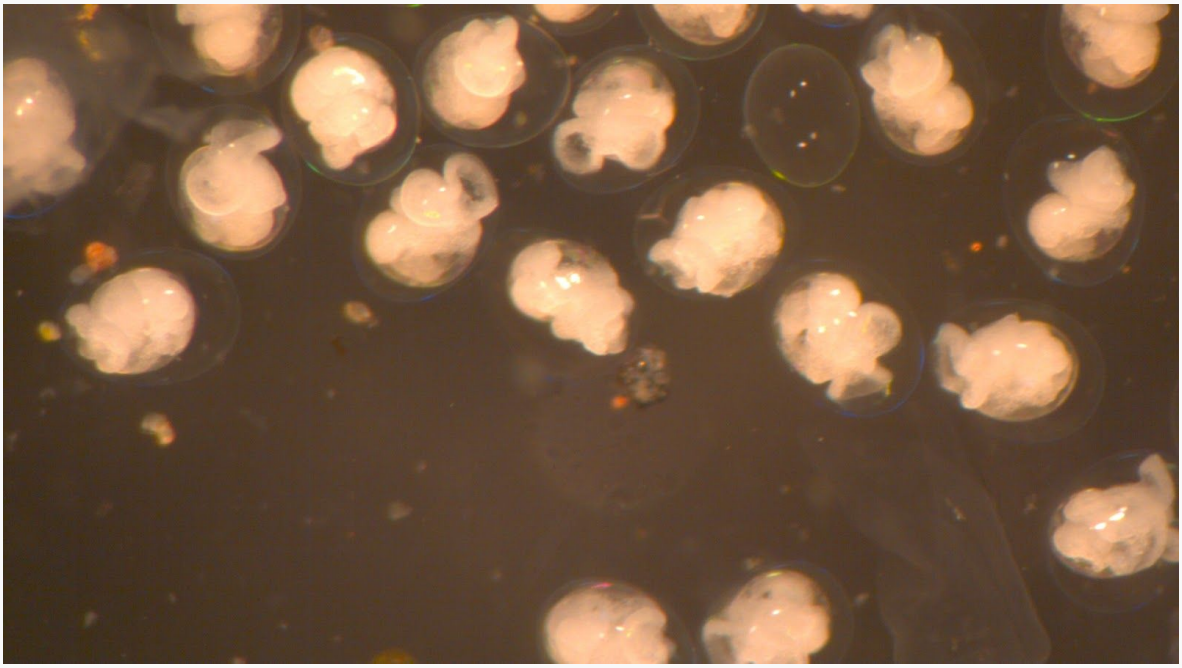
Nudibranch development photos: (Order of development: egg; early veliger; mid-veliger; late veliger)



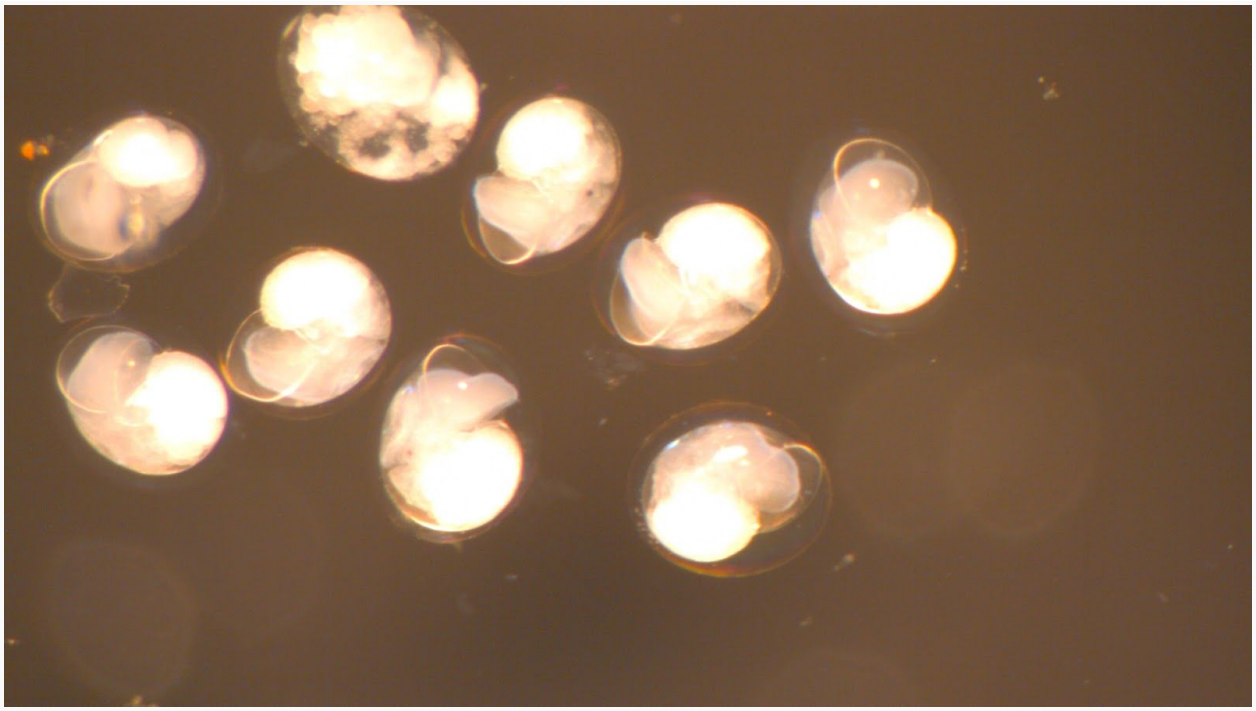
Healthy nudibranch (*Tritoniella belli)* eggs in early stage of development. At this point the cells are too numerous to count. Crary Lab, McMurdo Station, Antarctica. Photo by Aaron Toh (2019)



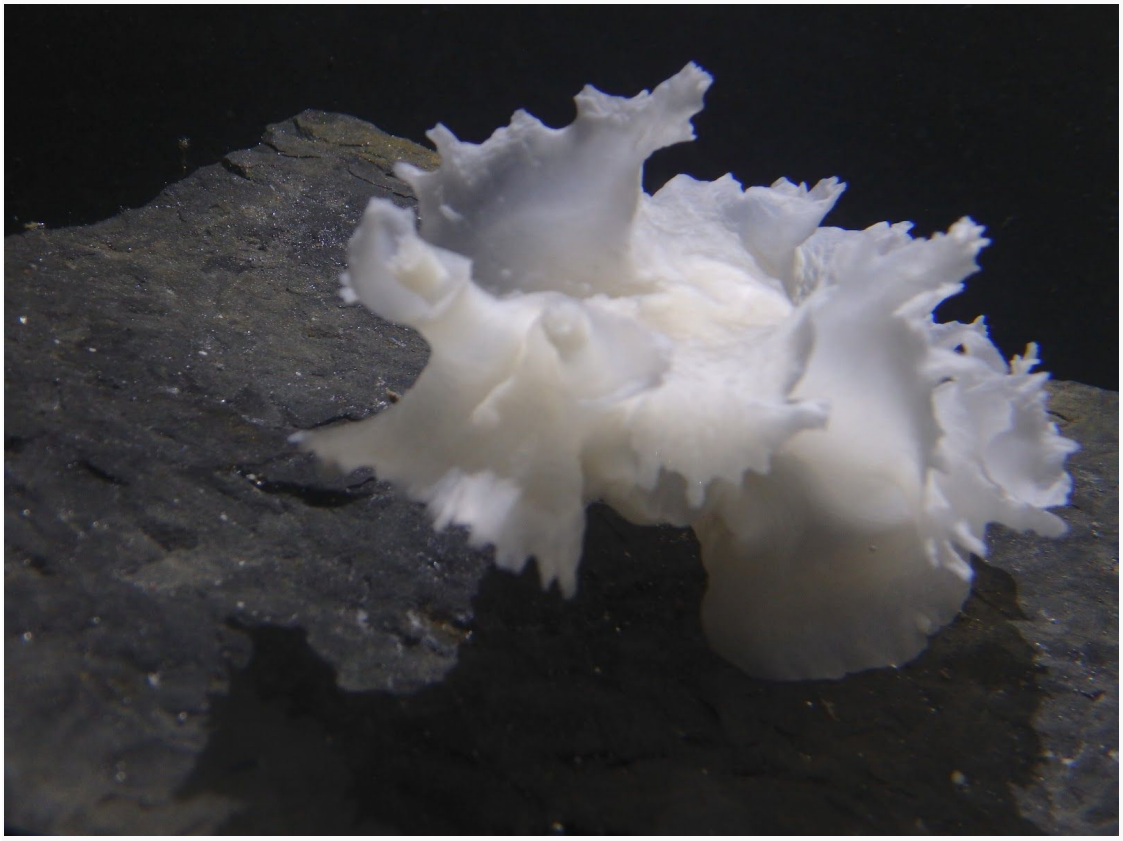
Healthy Early veliger stage of nudibranch (*Tritoniella belli)* development. Crary Lab, McMurdo Station, Antarctica. Photo by Aaron Toh (2019)



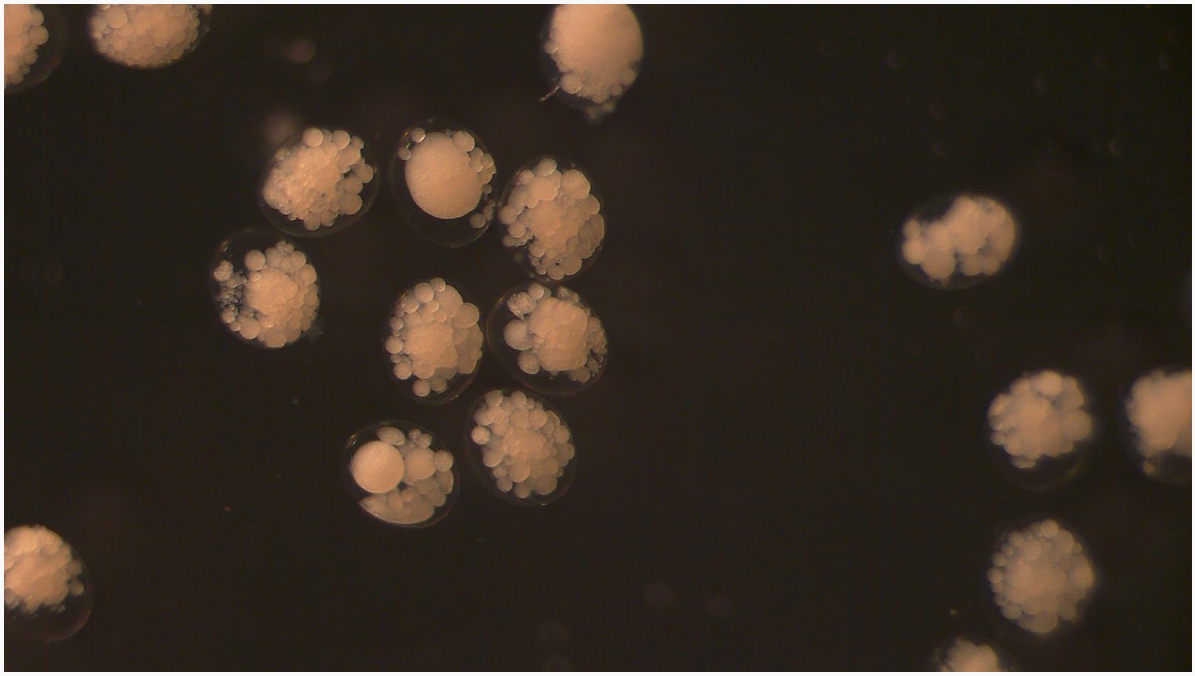
Healthy mid-veliger stage of nudibranch (***Tritoniella belli)*** development. Note the butterfly-like shape with cilia. Crary Lab, McMurdo Station, Antarctica. Photo by Aaron Toh (2019)



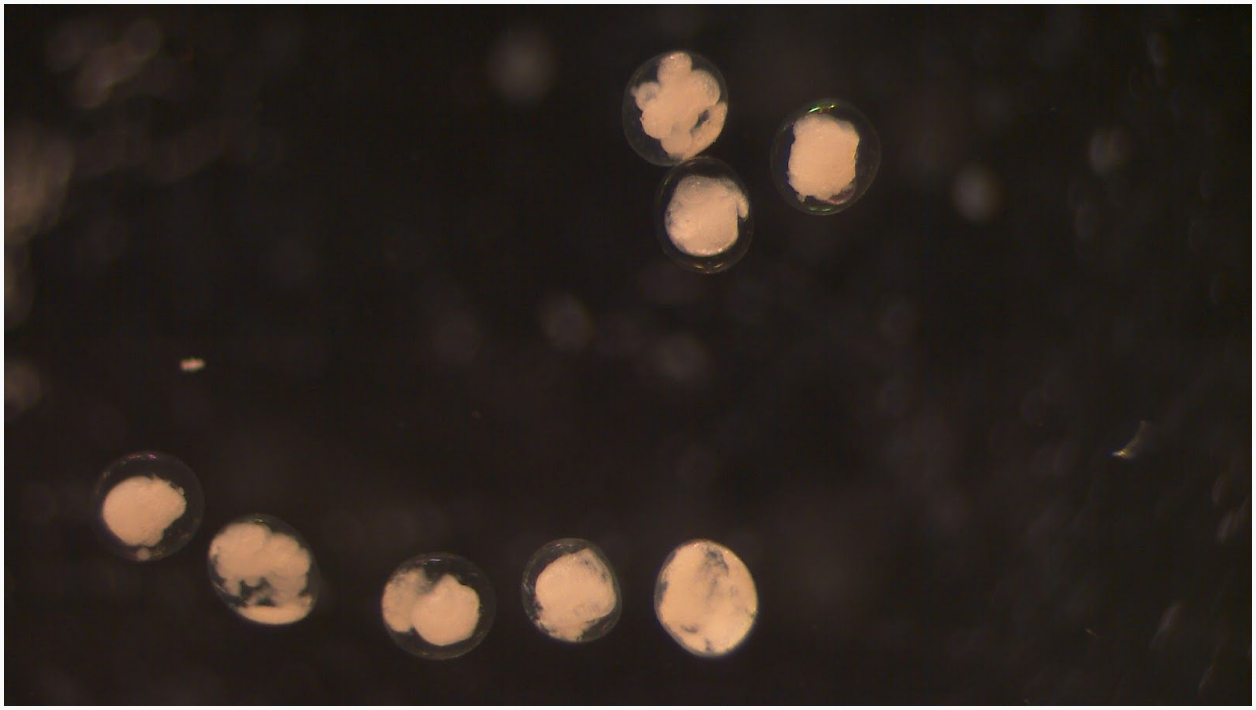
Healthy late veliger stage of nudibranch (*Tritoniella belli*) development. Crary Lab, McMurdo Station, Antarctica. Photo by Aaron Toh (2019)



Adult nudibranch (*Tritoniella belli*). Photo by Amy Osborne, Crary Lab, McMurdo Station, Antarctica courtesy of ARCUS (2019)

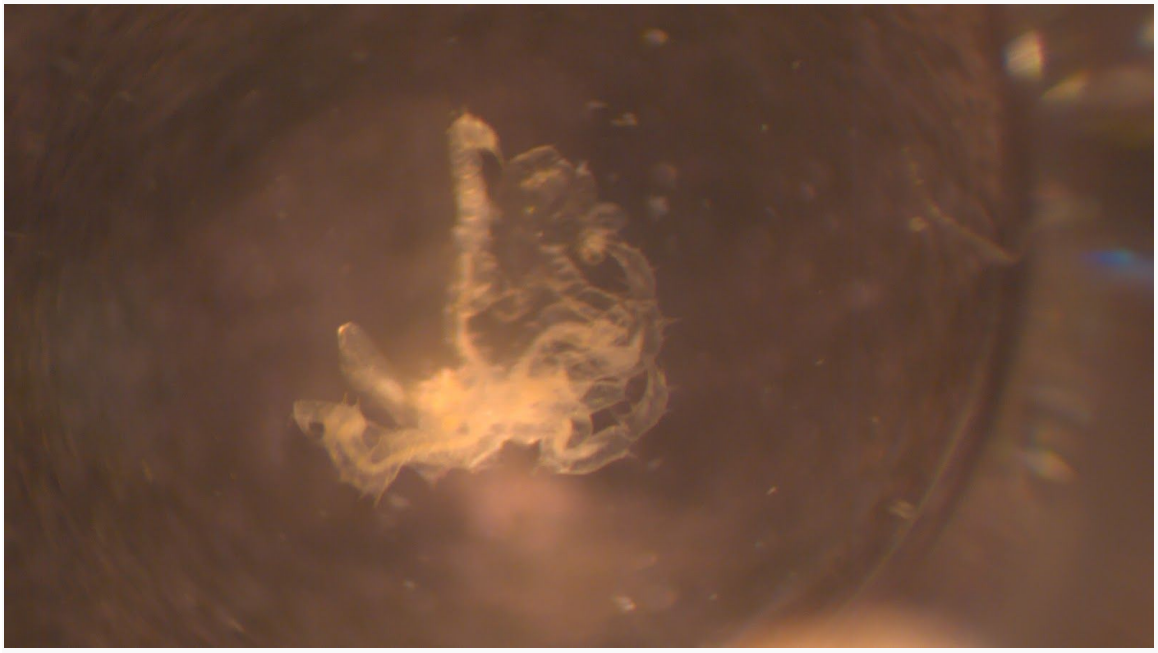


Unhealthy nudibranch eggs (*Tritoniella belli)*- grown under warmer conditions than normal. Crary Lab, McMurdo Station, Antarctica (Photo by A Toh, 2019)

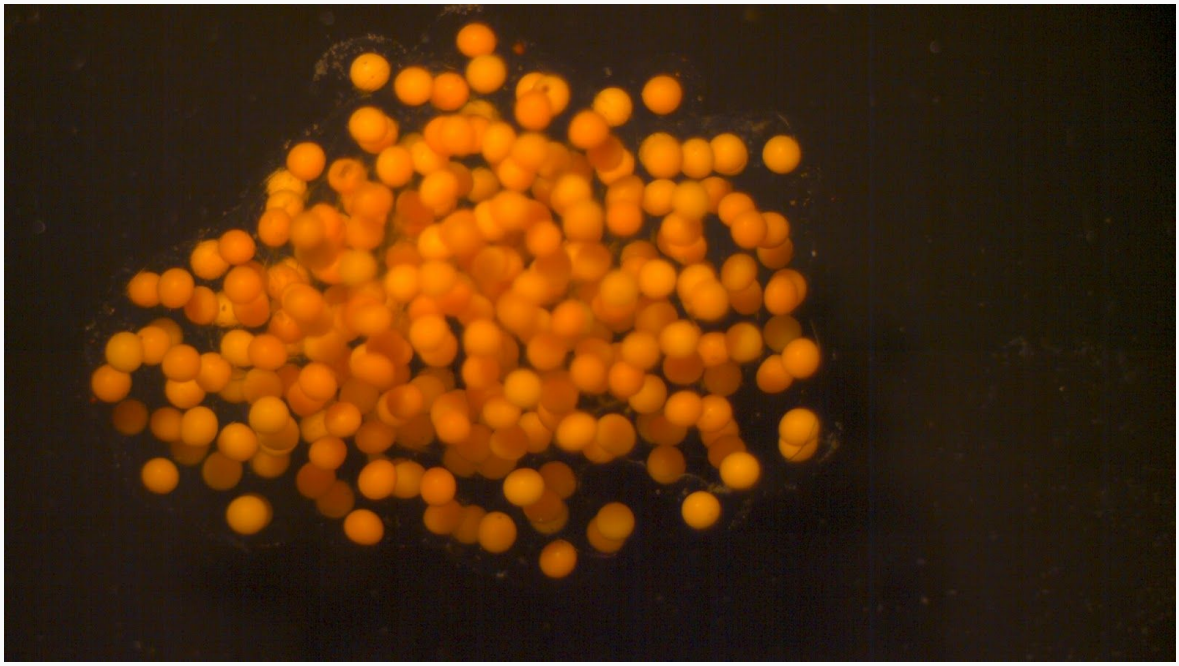


Unhealthy nudibranch (*Tritoniella belli*) grown under warmer conditions than normal. Crary Lab, McMurdo Station, Antarctica. (Photo by Aaron Toh, 2019)

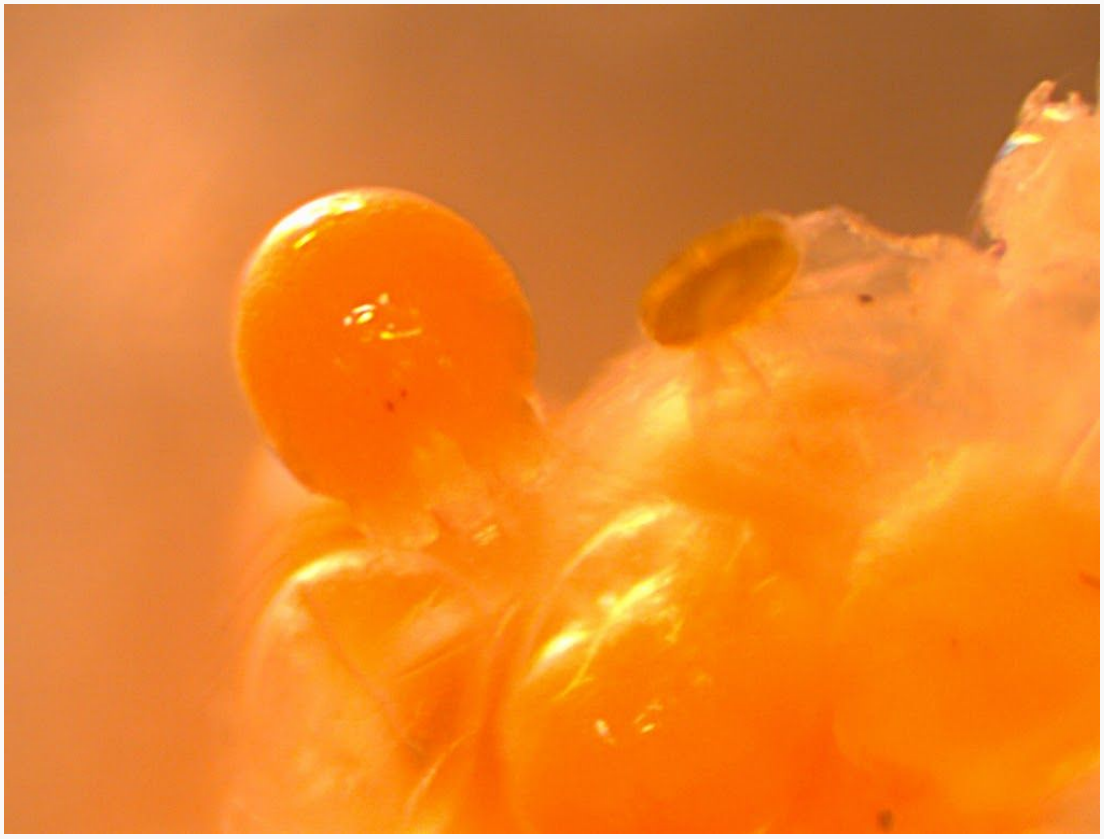
Sea Spider development photos (order of development: egg; Instar 1; Instar 2; Instar 3; adult)



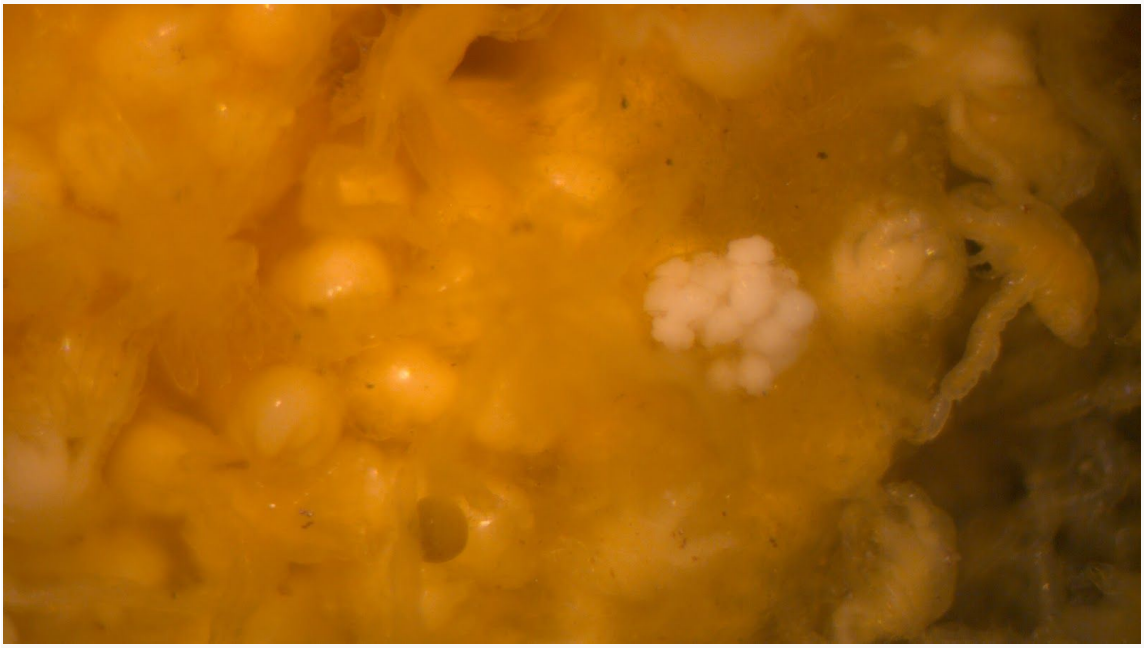
Late stage of sea spider development-Instar 3. Crary Lab, McMurdo Station, Antarctica. (Photo by Aaron Toh, 2019)



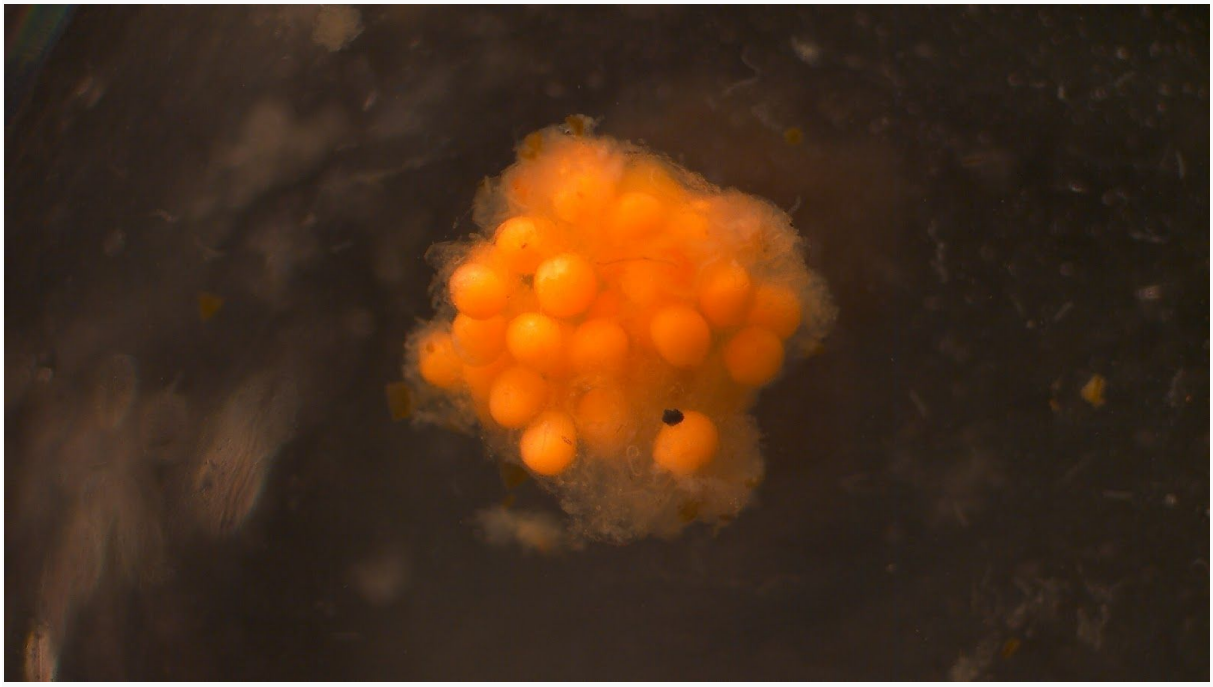
Sea spider (*Ammothea*) eggs. Crary Lab, McMurdo Station, Antarctica (Photo by Aaron Toh, 2019)



Instar 1 stage of sea spider development. Note the two tiny eyes, the proboscis, and the tiny legs that are beginning to form. Crary Lab, McMurdo Station, Antarctica (Photo by Aaron Toh, 2019)



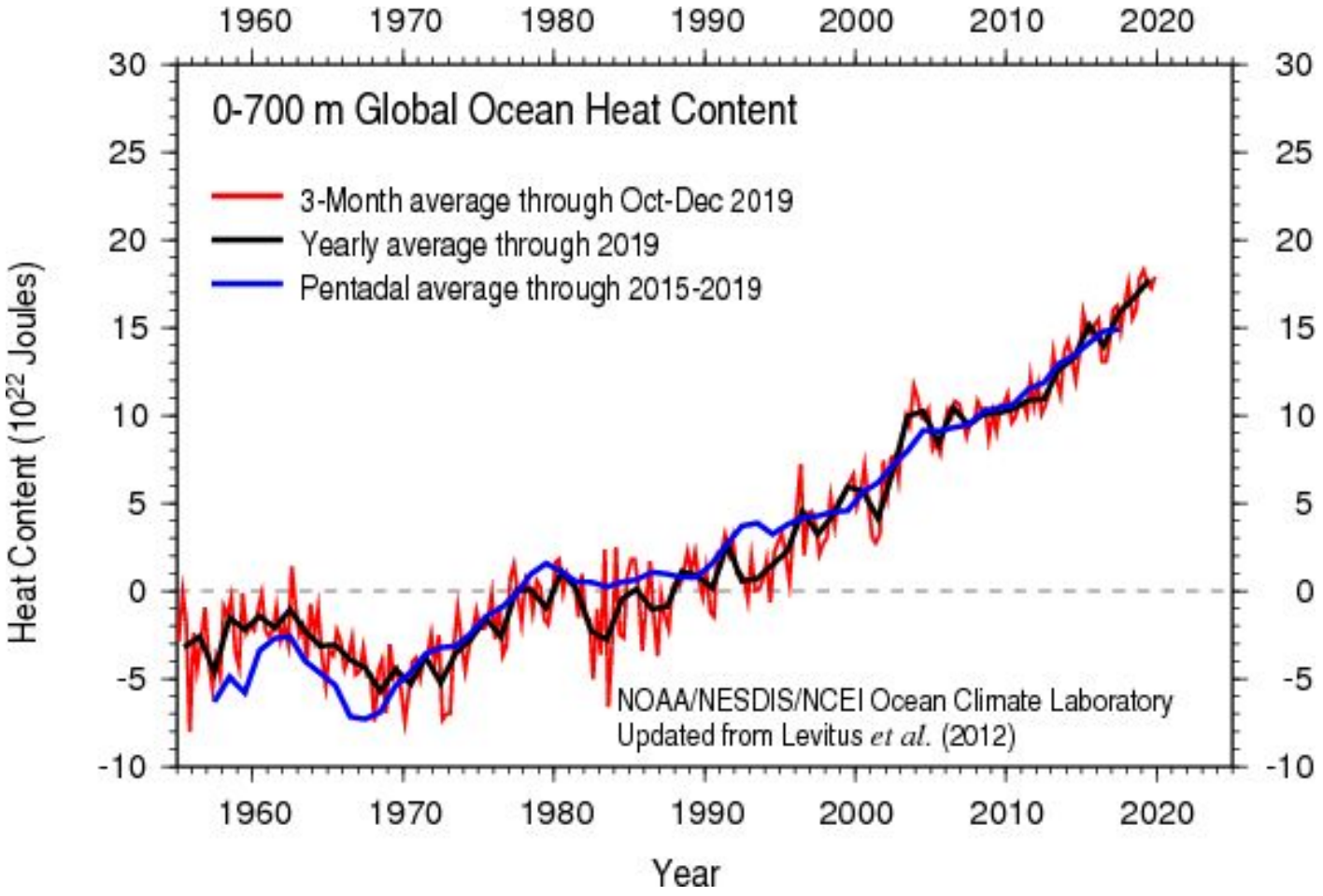
Sea Spider growth-Instar 2 Photo by Aaron Toh, Crary Lab, McMurdo Station, Antarctica 2019



Moldy Sea Spider (*Ammothea*) eggs growing under warmer than normal conditions. Crary Lab, McMurdo Station, Antarctica. (Photo by Aaron Toh, 2019)

Adult sea spider (Ammothea). Crary Lab, McMurdo Station, Antarctica. (Photo by Amy Osborne, 2019 Courtesy of ARCUS)

Graphs related to ocean temperature change

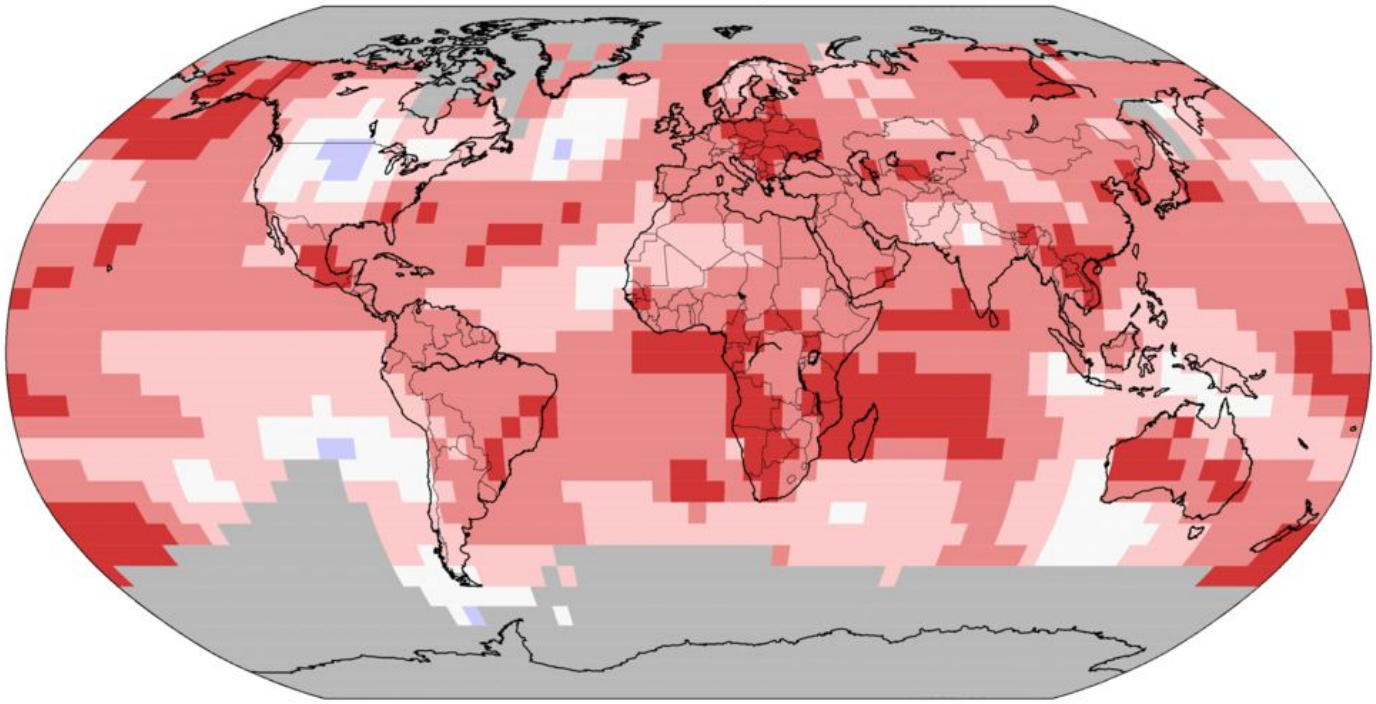


https://www.nodc.noaa.gov/OC5/3M_HEAT_CONTENT/

Land & Ocean Temperature Percentiles Jan–Dec 2019

NOAA's National Centers for Environmental Information

Data Source: NOAAGlobalTemp v5.0.0–20200108



Record Coldest | Much Cooler than Average | Cooler than Average | Near Average | Warmer than Average | Much Warmer than Average | Record Warmest

GHCNM v4.0.1.20200106.qfe