TEACHERS AND RESEARCHERS EXPLORING AND COLLABORATING

PolarTREC Informal Education Product Resource

Jumping Into Warming Seas

Amy Osborne

Thermal Sensitivity of Embryos and Larvae of Antarctic Marine Ectotherms

PolarTREC Expedition Page
https://www.polartrec.com/expeditions/thermal-sensitivity-of-embryos-and-larvae-of-antarctic-marine-ectotherms

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Overview

This lesson introduces students to the impacts of increasing ocean temperatures on marine life. Through this kinesthetic activity, students will learn more about marine ectotherms and what researchers in Antarctica have learned so far about how increasing temperature in Antarctic waters will affect their growth. Through the elaborate section of the activity students will connect what they learned about animals in Antarctica to the varying effect warming ocean temperatures are predicted to have on marine animals in California.

Objectives

- Students will be able to identify the challenges, like growing too quickly and producing unhealthy larvae, animals in the ocean are facing as ocean temperatures increase.
- Students will be able to recognize that marine life will be impacted in a variety of ways by the increase in ocean temperatures. Some animals will experience potential challenges, like an increase in growth rate, and others may benefit, like an increase in population and distribution, from increasing ocean temperatures.
- Students will be able to state the impacts that changes in the ocean ecosystem will have on living things within that ecosystem.
- Students will understand the role that researchers play in helping understand the impacts the changing ecosystems will have on the animals and plants that call them home.

Product Preparation

Summary of lesson

In this lesson, students will learn more about the life cycle of marine ectotherms that live in the consistently cold waters of Antarctica and about the research that's being done on the impacts of warming ocean temperatures on marine ectotherm growth. Students will then do an activity that involves going through a spinning jump rope. The spinning rope will begin to spin faster representing the challenges marine animals are facing as the ocean water temperatures increase. Some student "marine animals" will make it through the spinning rope as the rope spins faster and some will not. Students will connect the challenges that marine animals in Antarctica are facing to the challenges that marine animals along the California coast are facing as ocean temperatures rise.

Resource Details

Date

1 July 2020

Region

Antarctic

Completion Time

Less than a week

Grade

Middle School and Up

Permission

Download, Share, and Remix

Location

McMurdo Field Station, Antarctica

Expeditions

Thermal Sensitivity of Embryos and Larvae of Antarctic Marine Ectotherms

Author(s)

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Related Members

Amy Osborne

Amy Moran

Materials

"Story of an Antarctic Research Team" + photos (in Lesson Materials)

Graphs showing ocean temperature changes

Prior knowledge of students/lessons to do prior to this activity:

1. Students should know that the average global temperature is increasing due to global climate change and this increase in temperature also includes an increase in average ocean temperature.
2. If used by NatureBridge Educators - lessons to do prior to activity:
3. Greenhouse gas tag: demonstrates the effect that increased gases have on raising the earth's temperature.
4. Ocean Food Webs
5. Jump Rope Team Challenge (Lesson is below in Extensions)

Vocabulary:

- Currents
- Marine Ectotherms
- Endotherms
- Climate Change

Background Information:
As the average temperature of the global ocean is rising due to climate change, the ocean ecosystems are and will continue to be impacted. Scientists around the globe are studying the impacts that even small temperature changes might have on life in the ocean.

Due to the Antarctic Circumpolar Current (ACC), marine animals located in Antarctica have lived in a fairly stable environment for millions of years. The ACC, along with upwelling, means the ocean around Antarctica maintains a steady temperature throughout the year. This makes Antarctica a key location for scientists to research the effects that even small increases in ocean temperature will have on animals that live in the Antarctic marine ecosystem.

Dr. Amy Moran and her team of researchers traveled to Antarctica to study the impacts that increasing ocean temperatures will have on marine ectotherms like sea spiders and nudibranchs (aka sea slugs). They found that as ocean temperatures warm some of these animals are growing at a faster rate. Dr. Moran and her team are now studying how this rapid growth rate will affect the development of these animals. See Antarctic Sun article "Larvae La Vida Loca: How Will Warming Oceans Affect Young Invertebrates When They're At Their Most Vulnerable?" by Michael Lucibella for more information: To stay up-to-date on what Dr. Moran and her team are learning about the way warming seas will impact marine ectotherms see the website of the research team, Invertebrates in the Antarctic: Metabolism, Development, Biomechanics, and Polar Gigantism

throughout the globe (in Lesson Materials)

Map showing location of Antarctic Circumpolar Current (graphic included in "Story of an Antarctic Research Team" photos)

Pictures of sea spider and nudibranch development-"Stages of nudibranch and sea spider development" (in Lesson Materials)

Information cards about impacts of warming ocean temperatures on animals in California-"California Marine Animals Cards-Warming Ocean Impacts" (in Lesson Materials)

Long rope to act as jump rope that more than one person can go through-an old climbing rope or long piece of webbing can work.

Field or open area where you can spin a big rope

Mini-whiteboard and whiteboard marker or something you can use to record data so all students can see

Topic

Organisms and Their Environments

Oceanography

Climate Change

General Environmental Studies

Scientists predict that animals in the ocean will be impacted in a variety of ways. Scientists hypothesize that some animals in the ocean will increase in distribution and/or abundance (e.g. jellyfish, crown-of-thorns starfish, some species of nudibranchs) and some will decrease in distribution and/or abundance (e.g. salmon, sea lions, mussels). These impacts will affect ocean food webs across the globe.

Procedure

ENGAGE (10 minutes):

“Story of an Antarctic Research Team”
1. Ask students to find a comfortable seat and close their eyes. (You can also do this with eyes open and show the pictures as you tell the story.)
2. Tell students you are going to tell them a short story and they will visualize what they are hearing.
3. Read “Story of an Antarctic Research Team” (see attached resource)
4. Ask students to open their eyes. Share pictures of keywords and concepts from the story: sea ice, Pisten bully, sea ice road with flags, dive hut, divers with dry suits, nudibranch egg case, sea spider with eggs, dive tender, taking salinity and temperature measurements in the water, exploring underwater, nudibranch, sea spider, putting specimens into cooler. (see attached resource)
5. Explain that Dr. Amy Moran and her team in Antarctica are studying the impacts that warming ocean temperatures will have on marine ectotherms like sea spiders and sea slugs (at this point you can show pictures of adult sea spiders and nudibranchs aka sea slugs)
6. Tell students that warming oceans is one of the impacts that climate change is having on the ocean. You can show graphs of warming ocean temperatures. (see attached resource)
7. Ask students to write about the following... "What do you know about the challenges animals in the ocean are facing due to climate change?” “What questions do you have about the challenges marine animals are facing?”

EXPLORE (30-40 minutes):

Jump Rope Challenge
This activity will be done in several rounds (normal speed-2x, a bit faster-2x, and if there is time, even faster 2x) make a graph about how many people made it through Round 1, Round 2, Round 3, Round 4, Round 5, and Round 6 :
1. Tell students we are now going to do an activity about marine animals and warming ocean temperatures.
2. Explain that the researchers in Antarctica and researchers all over the world are studying the impacts that warming ocean temperatures will have on marine life.
3. Explain to the group that they are now all animals in the ocean and the spinning rope represents the ocean. If you want to you can have students become ocean animals that scientists have been studying. (Show pictures of sea spiders, nudibranchs, jellyfish, mussels) These animals are ectotherms. Explain that **endotherms**, often called warm-blooded, can regulate their body temperature from within and **ectotherms**, often called cold-blooded, depend on the environment around them for their body temperature.
4. The spinning represents challenges that ocean animals face. The students’ goal is to get everyone from one side of the spinning rope to the other side. Participants cannot walk around the rope-they must go through it. (If someone is hit by the spinning rope they don’t make it through.)
5. Tell students they will have two tries to get everyone through the spinning rope. At the end of each round, the number of students who have made it through the rope will be recorded on the mini-whiteboard.

Round 1 & Round 2- group has 2 chances-goal to get through the rope

6. Have another adult or student in the group help you turn the rope at a regular jump rope speed. The group needs to all get through the spinning rope to the other side.
7. After their first attempt, on the whiteboard record the number of students who made it through the spinning rope. Tell students they can meet and talk with each other before Round 2 to offer advice and ideas about how to get everyone through the rope.
8. Record how many students make it through on Round 2

Round 3 & Round 4-Rope spins faster-2 chances to get through the rope now spinning faster

9. Tell students that, as we were just talking about, the temperature of the ocean globally is increasing.
10. Tell students that since the ocean temperatures are rising some marine animals will have more challenges so the game will become more challenging. To represent the increase in water temperature in the ocean, the rope will now spin faster than it was spinning before. Ask students to predict how many students they think will make it through the rope now that it's spinning faster.
11. Spin the rope faster and have students try to get through it. Just like in Rounds 1 & 2 give students a chance to talk in between the rounds and record how many students make it through each round.

Rounds 5 & 6 (If there is time)

12. Talk about other challenges animals are facing in addition to rising temperatures.
    Spin rope faster and/or add additional challenges- (Examples: People now have to go through 2 at a time, people now have to crawl to get through the rope or jump once or hop through the rope.)
13. Share the data that was gathered from the different rounds showing how many students made it through each round. Graph the information.

Debrief jump rope activity

- Ask students who made it through the spinning rope to the other side what helped them get through the spinning rope? Were they able to adapt to the situation presented to them?
- Ask students who didn't make it through what was their biggest challenge? If they had a chance to go through the rope again would they change what they did to try to make it through?
- Was it helpful to talk in between the rounds? Do animals in the ocean have a chance to talk about the challenges they are facing and learn from each other about how to deal with those challenges? How quickly do you think marine animals can adapt to changes in their environment?
- Tell students that scientists are researching marine animals to determine if and how they might be able to adapt to warming ocean temperatures.
- Tell students that scientists in Antarctica have been studying some animals like sea spiders and nudibranchs-aka sea slugs-and have found that they will grow faster as the oceans warm. Show pictures of sea spider and nudibranch eggs under healthy conditions and sea spider and nudibranch eggs in water that is warmer than normal. (see attached resource)

EXPLAIN (10-20 minutes):

1. Have students look at the graph created during activity. Ask what they notice.
2. Tell students some animals will struggle as the ocean temperatures rise. Connect to animals that are predicted to thrive and animals that are predicted to be stressed as ocean

temperatures increase. Cold water species will most likely be impacted more than warm water species. Warm water species can change locations whereas cold water species will be left with no place to go. Animals that made it through rope every time are highly adaptable like jellyfish. Animals that struggled every round are already facing challenges and are highly sensitive like coral, krill, and fish. For some species, like mussels, the impacts will vary even within the same species. A lot is still unknown so scientists are continuing to conduct long-term studies to determine the impacts of warming oceans on marine life.

3. Continue the Antarctic story. When researchers and divers brought animals back to the aquarium they used their eggs to conduct experiments. The eggs were placed in incubators at different temperatures and researchers checked on the growth each week.
4. Provide students photos with captions of the life cycle of nudibranchs and sea spiders (see attached) as well as visuals of sea spider and nudibranch eggs growing under increased temperatures. What do you notice?
5. Since the ocean is a web of ecosystems, the impacts go beyond just individual species. Entire marine food webs and the ocean community will most likely be impacted as some species die or eat less and its predators, prey, and competitors are affected. For more information see the Monterey Bay Aquarium's article "Climate change produces complex effects on marine communities"

ELABORATE (15-20 minutes):

Connect to local animals by sharing information cards about:

- Sea nettles
- California mussels
- Nudibranchs
- Copepods
- Chinook salmon
- Sea lions

1. Split students into 6 small groups.
2. Write down a list of the animals above. In small groups, the students predict what they think will happen to each of the listed California marine animals as sea temperatures increase.
3. Give each group a California marine animal card to read that has information about what scientists suggest will happen to each animal as the sea temperature increases. (Sea nettle, California mussels, Aeolid Nudibranch-*Phidiana hiltoni*, Copepod, Chinook Salmon, Sea Lion)
4. Each small group can then share with the big group what they learned about their animal.

EVALUATE (10 minutes):

1. **Option 1:** Tell students to choose one of the marine animals you learned about in this lesson. Write or draw a short story or comic strip of their life as the ocean begins to warm.
2. **Option 2:** Ask students to draw two different pictures: One picture of what they think the ocean looks like now and what they think the ocean will look like in the future as the oceans warm up.
3. **Revisit initial question:** "What do you know about the challenges animals in the ocean are facing due to climate change?" "What questions do you have about the challenges marine animals are facing?"

Timeline

1.5-2 hours

Extension/Adaptations

- Add in other challenges that marine animals are facing like a change in oxygen levels, predators, and ocean acidification. (For example, you could discuss how, as water warms, ectotherms have an increased need for oxygen and, as a result, as ocean temperatures warm more oxygen is being removed from the water by ectotherms so oxygen concentrations decrease.) Do the jump rope challenge again but this time you can add additional challenges to the game like students needing to hop through the rope, crawl through the rope, or go through the rope as a pair with their feet attached to represent the additional challenges animals are facing in the ocean.
- For younger students: To make it easier for younger students don't spin the rope, instead keep it on the ground and wiggle it.
- For older students: Read some of the articles listed in the resources section about the impacts climate change is having on marine life. Ask students to share their thoughts about all of the challenges.
- For NatureBridge educators and educators with access to hermit crabs: follow up with the Hermit Crab Temperature Inquiry lesson.
- End on a positive note: Share ways that students can take action to mitigate climate change.
- Equity & Inclusion Extension-connect the ease and challenges students have getting through the rope to privileges we are born with to make it through challenges
- Social and Emotional Learning Extension- after the activity, ask students how they adapt to changes in life-who helps you through the rope?
- Team building Extension/Lesson-Add a team-building element to the spinning rope activity. (This is the original version of the Jump Rope Challenge which is a commonly used outdoor education team building activity that can also lead into an introduction to scientific inquiry) Everyone must make it from one side of the spinning rope to the other. If a person is hit by the rope or doesn't make it through the whole group starts over again. If the group did this quickly and you have time try making this activity more difficult:

1. Try different variations on how the group must get through the rope. Examples might be: trying it one at a time, then make one jump in the rope and get to the other side, then try it without missing a beat of the rope between people.
2. Try in pairs or triplets.
3. Once participants can fairly easily get through the rope, make it a harder team challenge that introduces inquiry by choosing a pattern, without telling them, that they must use to get everyone through the rope. (For example, the facilitator might decide, without telling the group, that the pattern needs to be one person goes under, then two people go under, then one person goes under, then two people go under. The participants try different variations to figure out the pattern. When they are following the pattern correctly the rope keeps spinning. If they mess up the pattern the rope stops spinning and they must start over again.)

Team building Debrief:

Watch for communication, decision making, and working together.

Ask students the following questions:

- How did you communicate? Was everybody on board with what was happening?
- Did anyone step up as a leader? Was this done in a good way?
- How did you react when people didn't make it through the rope?
- How did it feel to be the person who didn't make it through the rope?
- How do you think this relates to the rest of life?

Transferability

- All educators can connect local changes and phenomena to this lesson.
- All educators can use the GLOBE or iNaturalist programs to observe and record sightings of local species and to observe changes in behavior, including migration, blooming, reproduction over time.

Resources

Resources related to Antarctic research on marine ectotherms:
Lucibella, Michael (2020, January 6) “Larvae La Vida Loca: How Will Warming Oceans Affect Young Invertebrates When They're At Their Most Vulnerable?” *Antarctic Sun*. Retrieved from https://antarcticsun.usap.gov/science/4413/

Resources related to increasing ocean temperatures impact on marine animal distribution and abundance:
Borunda, Alojandra (2019 August 14) “Ocean Warming, Explained.”, *National Geographic*. Retrieved from https://www.nationalgeographic.com/environment/oceans/critical-issues-s…

Tucker, Abigail (2010 August) “Jellyfish: The Next King of the Sea.” *Smithsonian Magazine* Retrieved from https://www.smithsonianmag.com/science-nature/jellyfish-the-next-king-o…

Rapp Learn, Joshua (2018 October 8) “Venomous Sea Creatures on the Rise Thanks to Climate Change.” *National Geographic*. Retrieved from https://www.nationalgeographic.com/environment/2018/10/climate-change-i…

California impacts:
Schwing, Franklin B. (2005) “The Impact of Climate Change on California’s Marine Ecosystems: Beyond Sea Level Rise” NOAA Fisheries Service Retrieved from https://coastal.ca.gov/climate/Schwing_Ecosystems.pdf

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” includes information about marine animals including nudibranchs, copepods, and sea lions. Retrieved from https://oehha.ca.gov/media/downloads/climate-change/report/2018caindica…

Mussels:
Simons, Eric (2019, June 26) “California’s Early June Heat Wave Cooked Coastal Mussels in Place.” *Bay Nature* Retrieved from https://baynature.org/2019/06/26/californias-early-june-heat-wave-cooke…
Hines, Sandra (2006, June) “Mussel strain: Same species responds differently to same warming depending on location.” *University of Washington News* Retrieved from https://www.washington.edu/news/2006/06/06/mussel-strain-same-species-r…

Resources related to global climate change and the ocean:
NOAA “Assessing the Global Climate in 2019”: https://www.ncei.noaa.gov/news/global-climate-201912
NOAA Global Climate Report: https://www.ncdc.noaa.gov/sotc/global/202001
NOAA Climate at a Glance (you can choose the month and start/end year to create a time series of surface temperature anomalies): https://www.ncdc.noaa.gov/cag/global/time-series/globe/ocean/1/1/1880-2…

Assessment

- Students will create before/after pictures of the ocean as temperatures warm.
- Students will create a story or comic strip of a marine animal living with rising ocean temperatures.
- For English Language Learners or younger students: Students collaboratively create a poster of what is happening during activity.
- Everybody has to write, each person has a different color marker. Create a picture of what researchers think might happen to ocean animals due to warming oceans. (Four squares- drawing, words, predictions)

Author/Credits

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Adapted from “Jump Rope Challenge” by Headlands Institute, now NatureBridge, and a leadership lesson commonly used in outdoor education

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

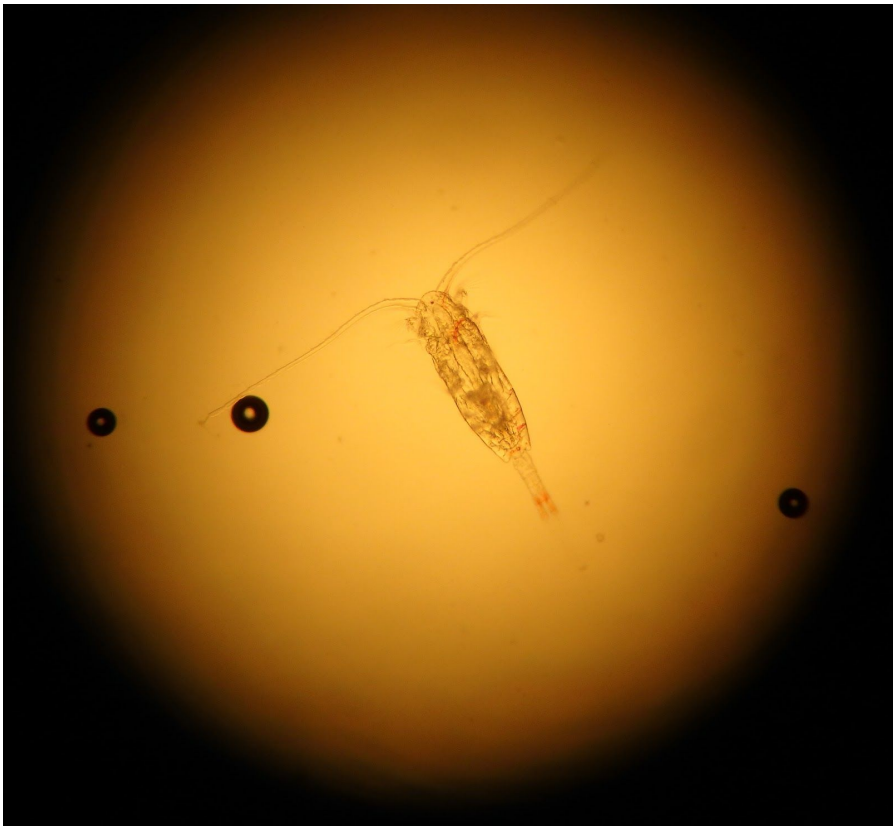
Nudibranch aka sea slug (*Phidiana hiltoni*) Photo by Bruce Wight from The Sea Slug Forum
http://www.seaslugforum.net/find/phidhilt

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.

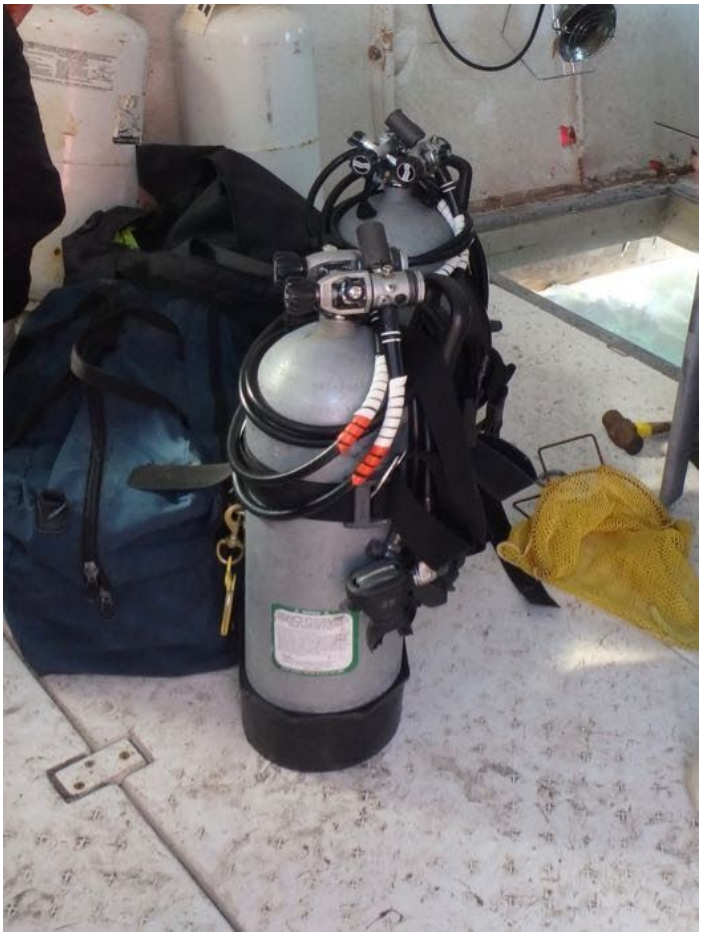
Photos for “Story of An Antarctic Research Team”

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

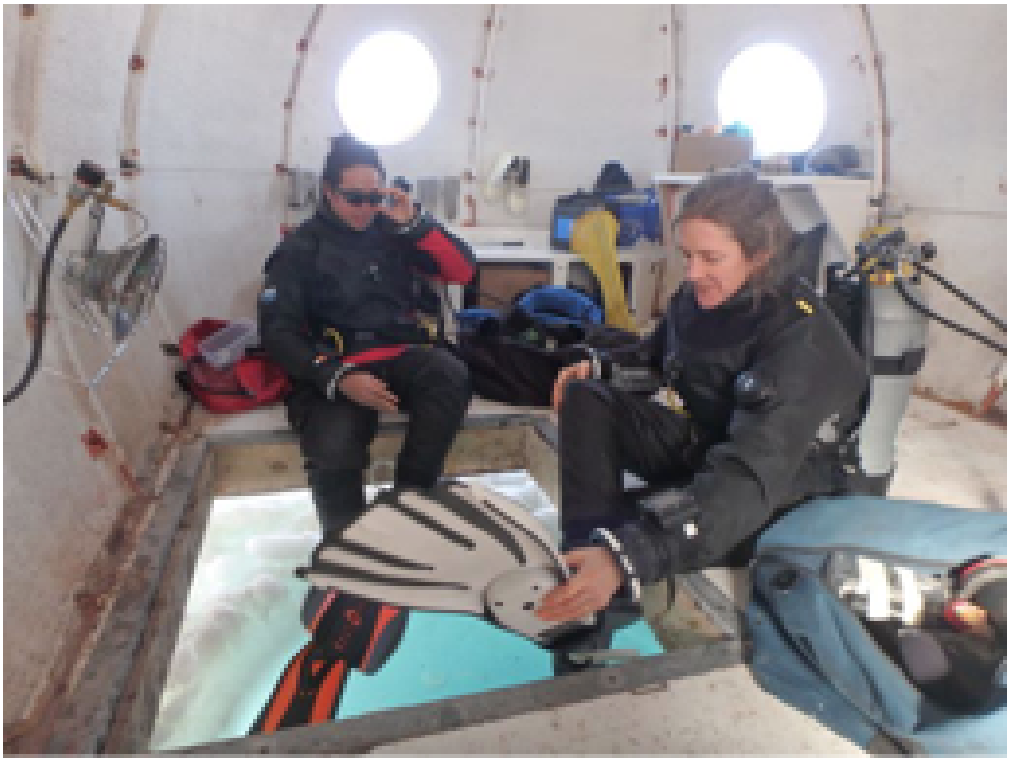
Pisten Bully on the sea ice near McMurdo Station, Antarctica. Photo by Amy Osborne courtesy of ARCUS

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

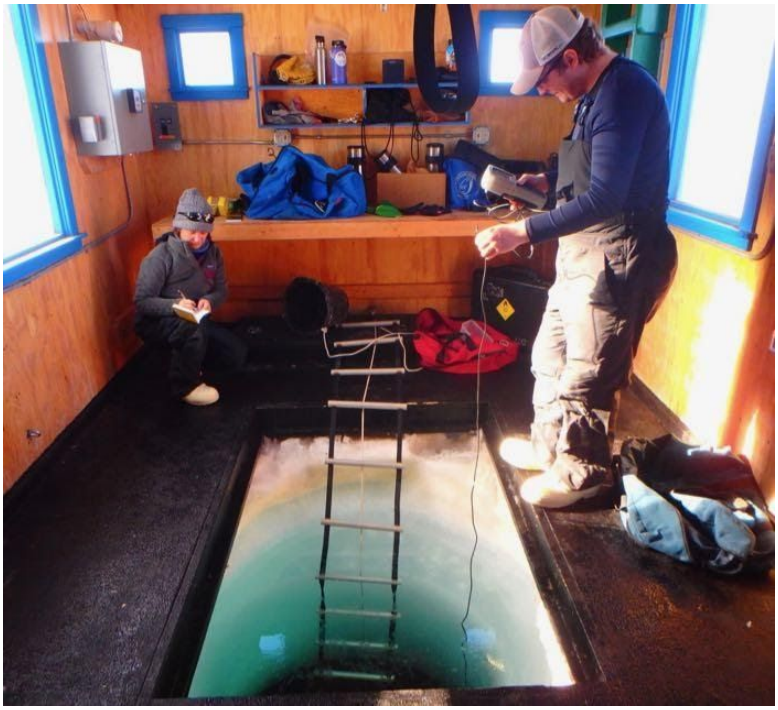


Dressed in dry suits, science divers and researchers Dr. Amy Moran and Aaron Toh prepare to dive through a hole in the ice into the frigid waters below. Photo by Amy Osborne courtesy of ARCUS

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

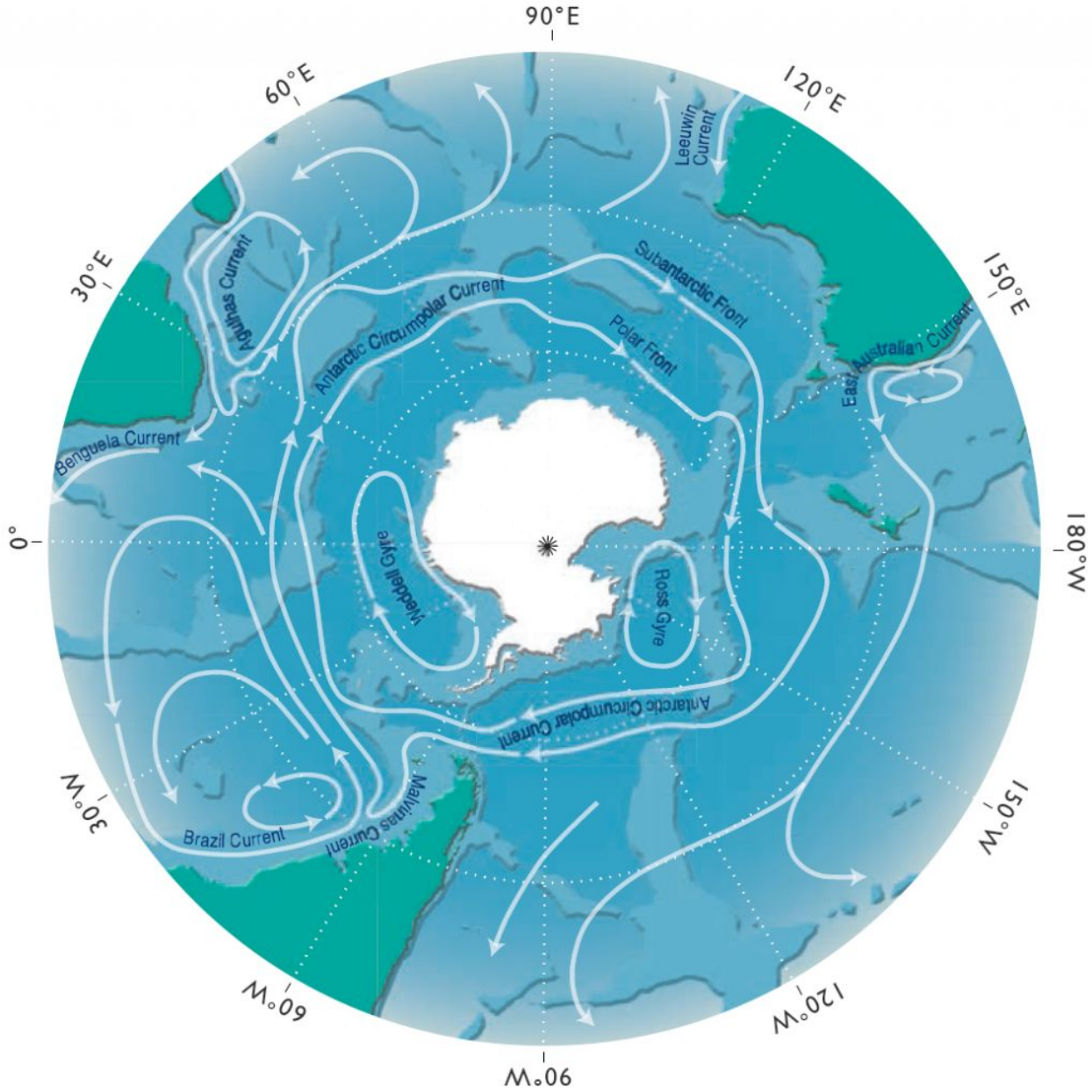
Researcher Dr. Amy Moran and Graham Lobert put sea spiders into a cooler of sea water to transport them back to the lab. Photo by Amy Osborne courtesy of ARCUS

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

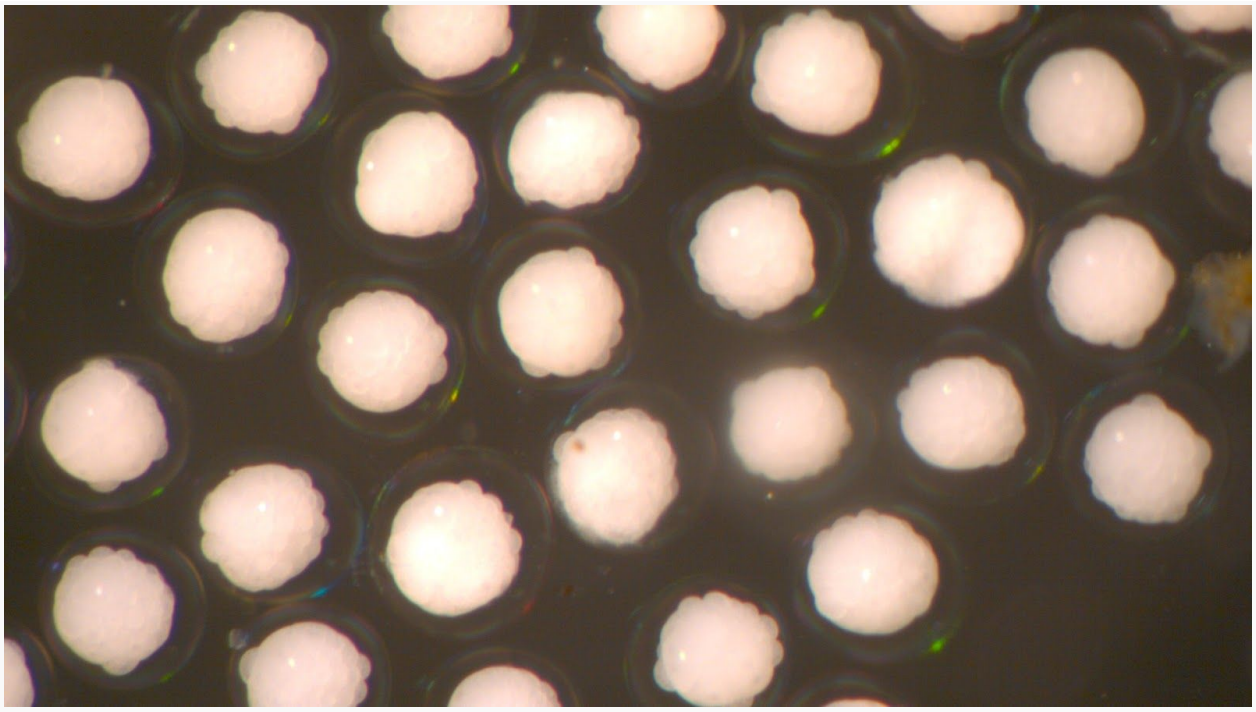
Adult nudibranch (*Tritonia challengeria*) Photo by Amy Osborne, Courtesy of ARCUS

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

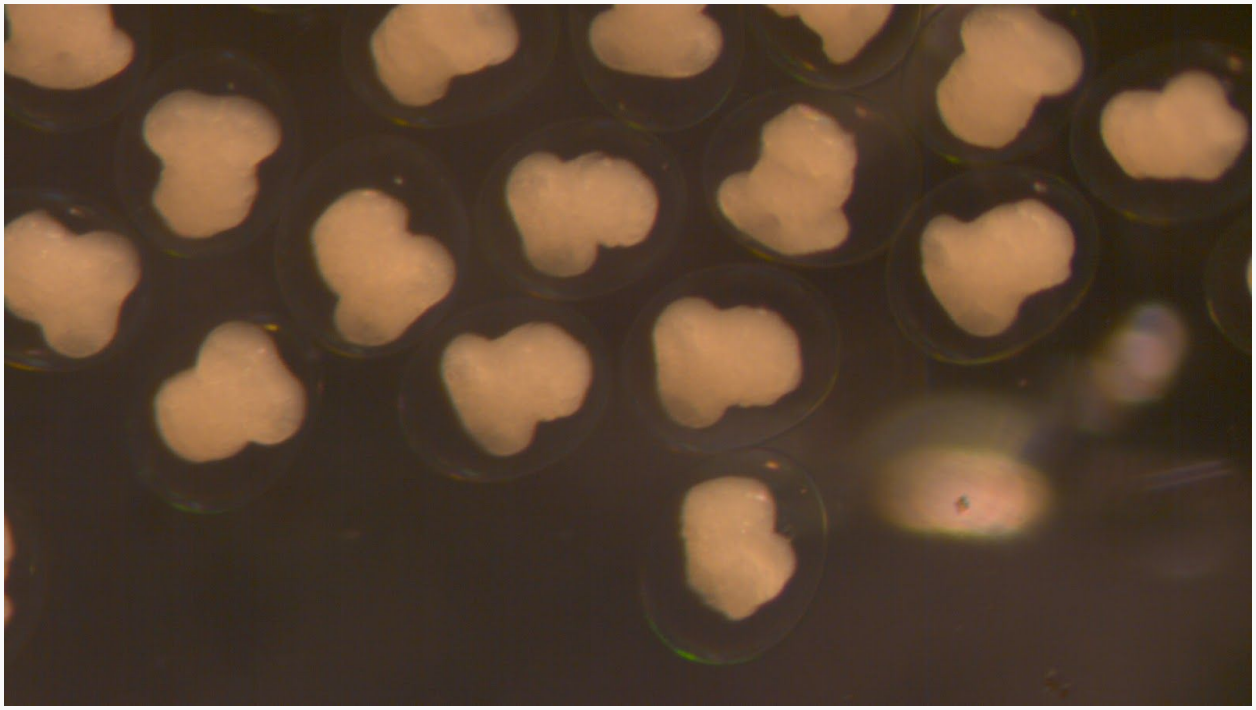


"The major ocean currents south of 20°S are shown by the arrows. The largest current in the world, the Antarctic Circumpolar Current, circles from west to east around Antarctica. This current creates a fairly isolated marine ecosystem in the ocean around Antarctica. As a result, warm subtropical waters 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)

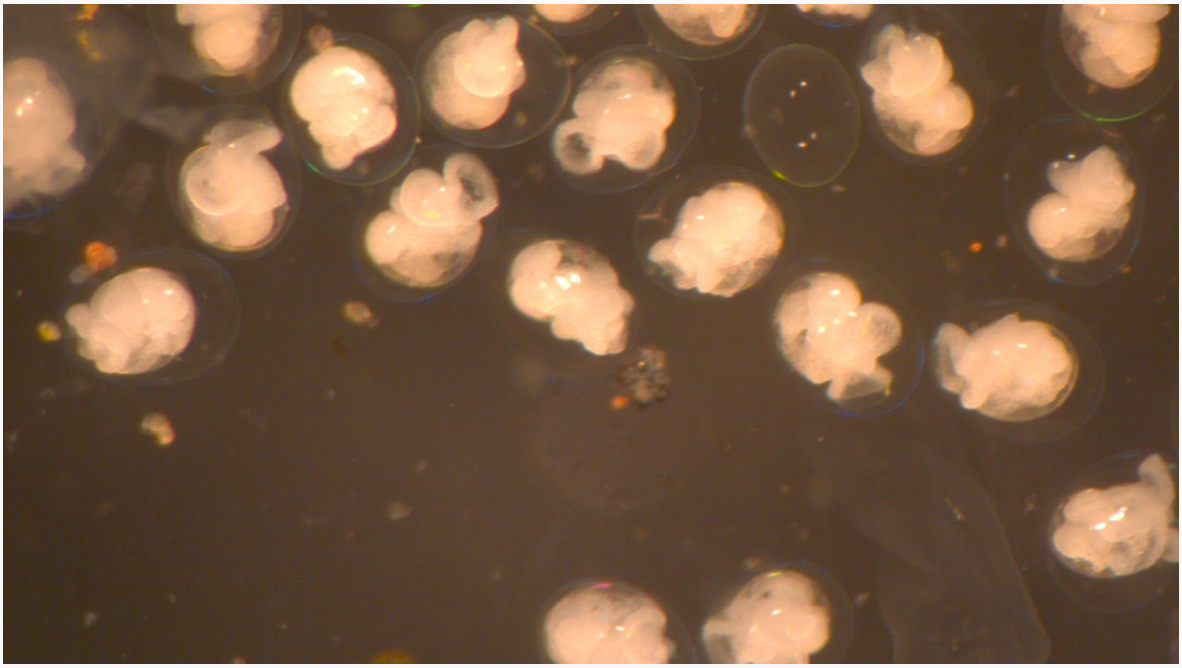
Nudibranch development photos: (Order of development: egg; early veliger; mid-veliger; late veliger)



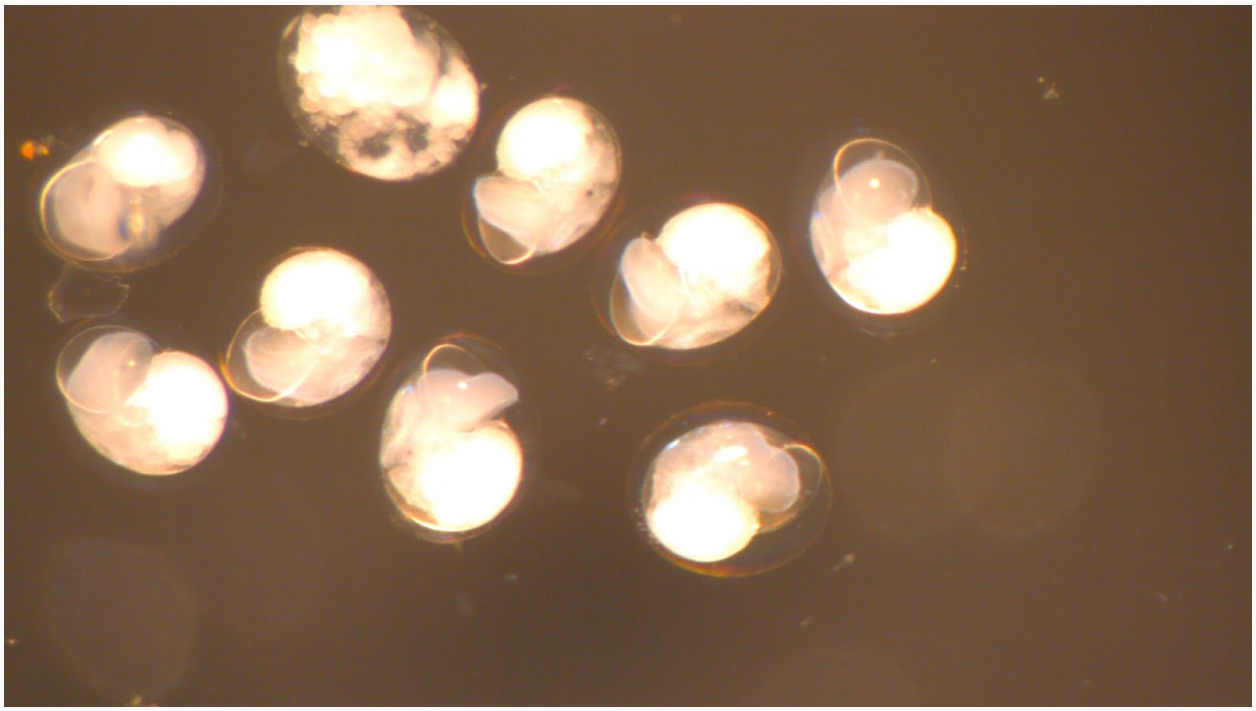
Healthy nudibranch (*Tritoniella belli)* eggs in early stage of development. At this point the cells are too numerous to count. Crary Lab, McMurdo Station, Antarctica. Photo by Aaron Toh (2019)



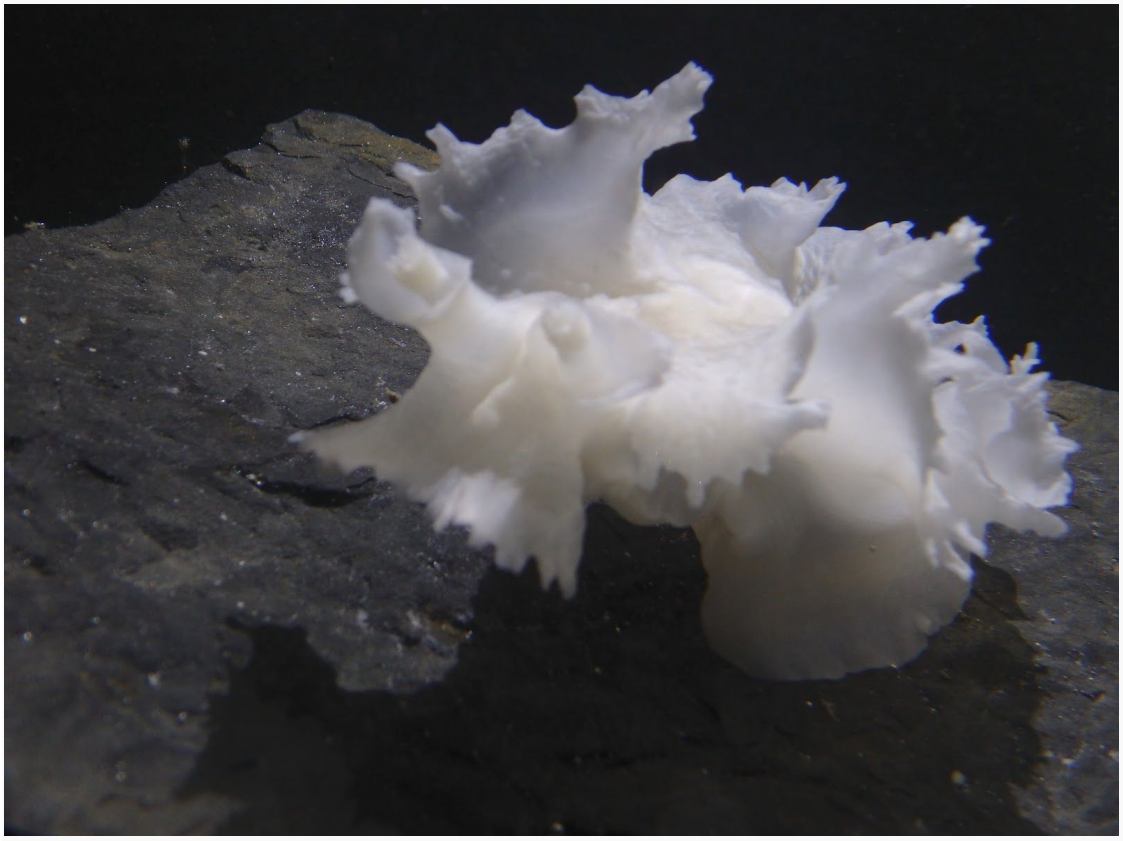
Healthy Early veliger stage of nudibranch (*Tritoniella belli)* development. Crary Lab, McMurdo Station, Antarctica. Photo by Aaron Toh (2019)



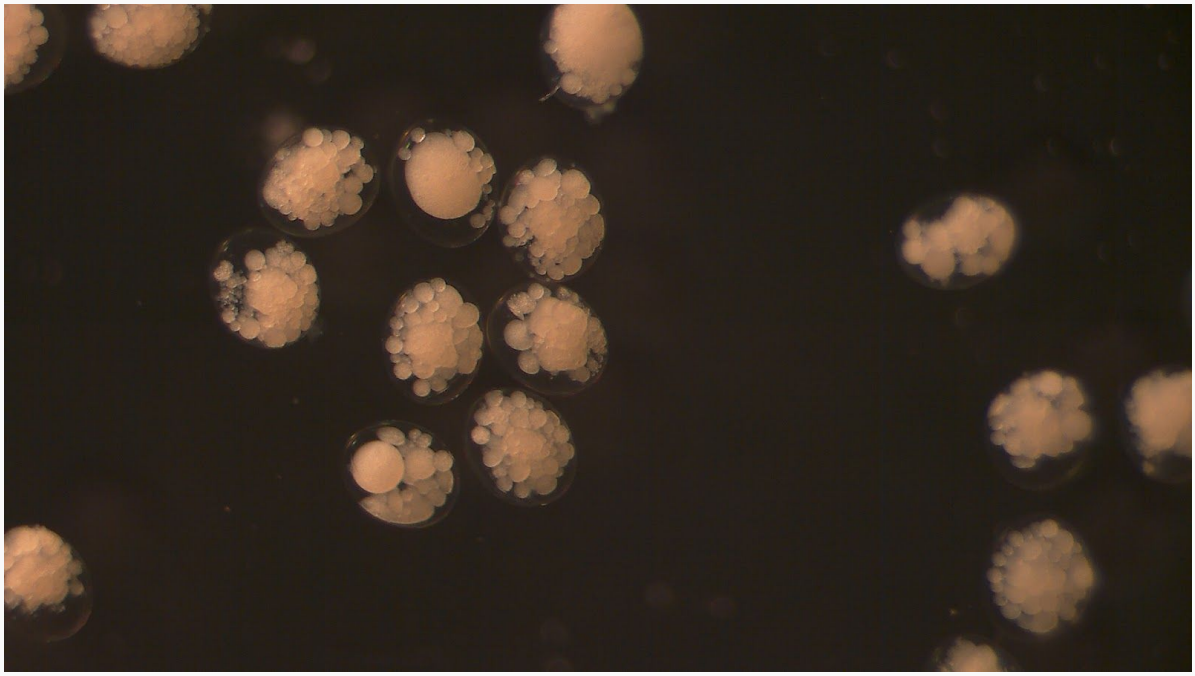
Healthy mid-veliger stage of nudibranch (***Tritoniella belli)*** development. Note the butterfly-like shape with cilia. Crary Lab, McMurdo Station, Antarctica. Photo by Aaron Toh (2019)



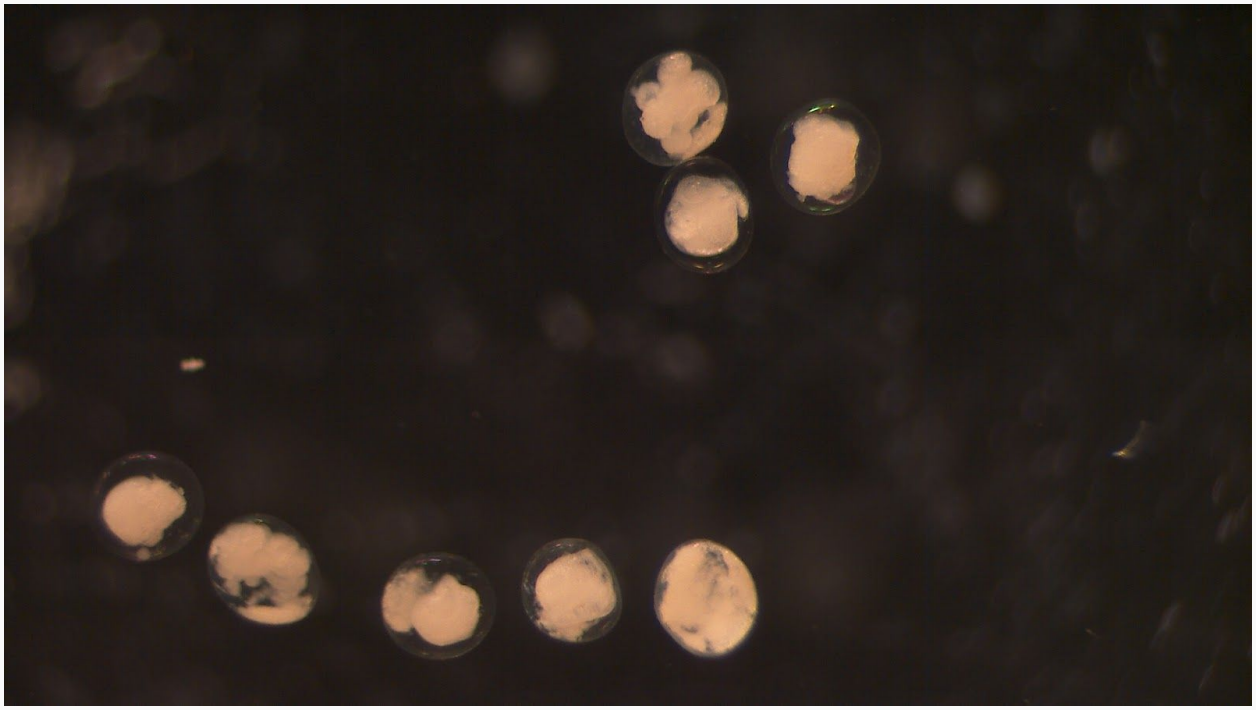
Healthy late veliger stage of nudibranch (*Tritoniella belli*) development. Crary Lab, McMurdo Station, Antarctica. Photo by Aaron Toh (2019)



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

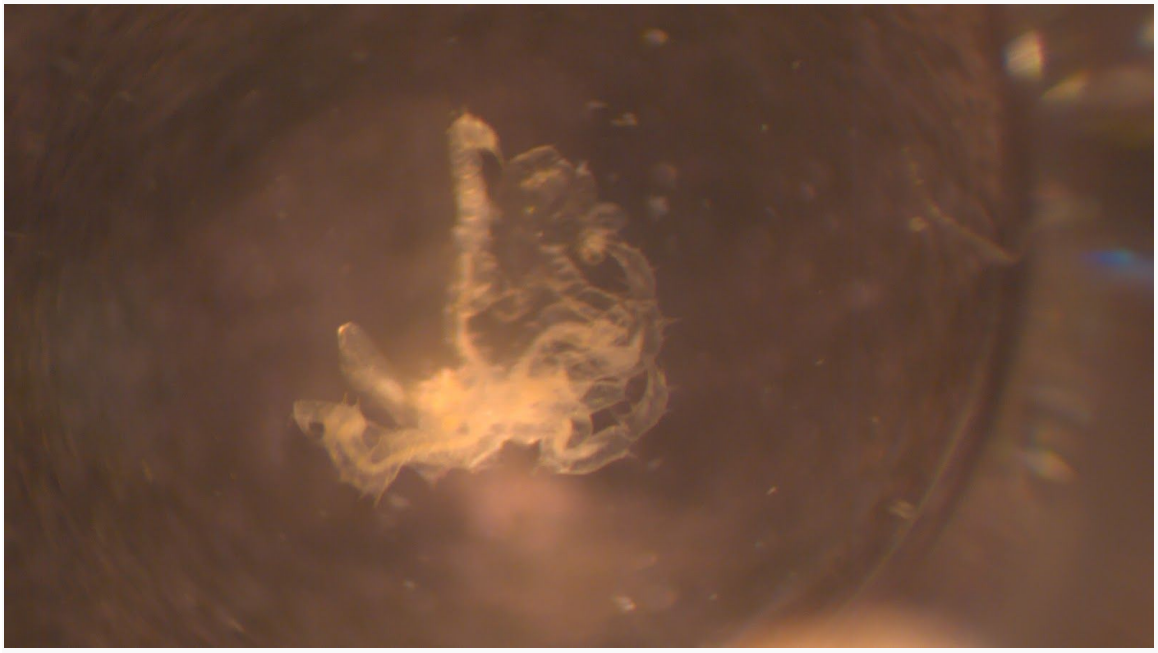


Unhealthy nudibranch eggs (*Tritoniella belli)*- grown under warmer conditions than normal. Crary Lab, McMurdo Station, Antarctica (Photo by A Toh, 2019)

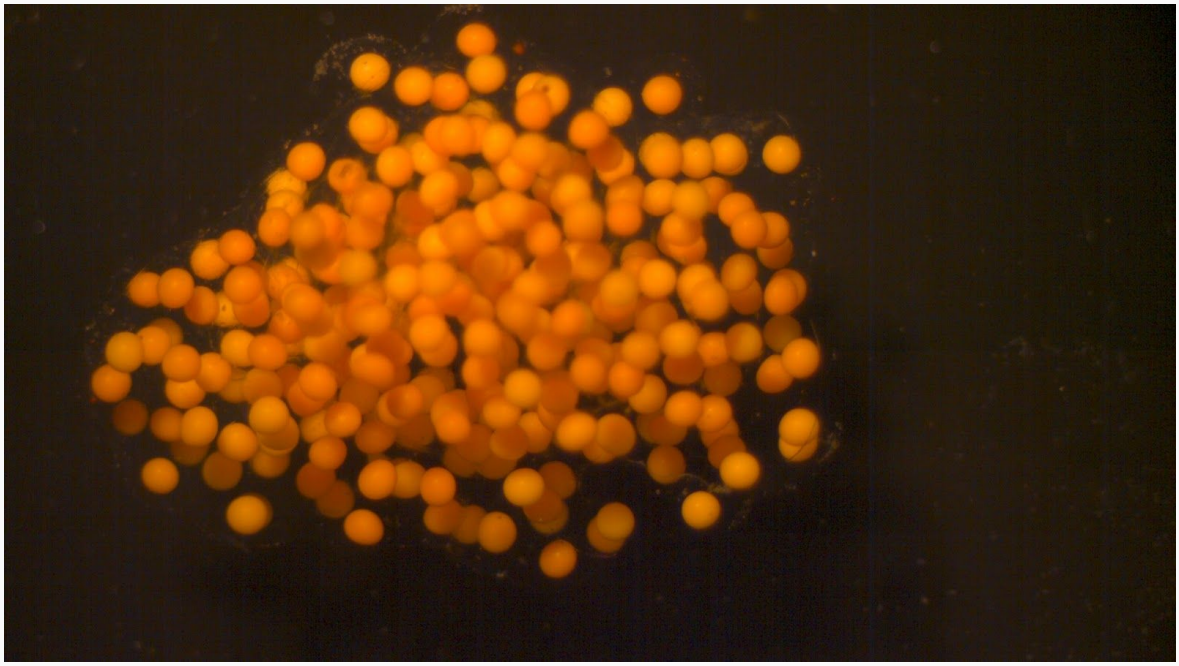


Unhealthy nudibranch (*Tritoniella belli*) grown under warmer conditions than normal. Crary Lab, McMurdo Station, Antarctica. (Photo by Aaron Toh, 2019)

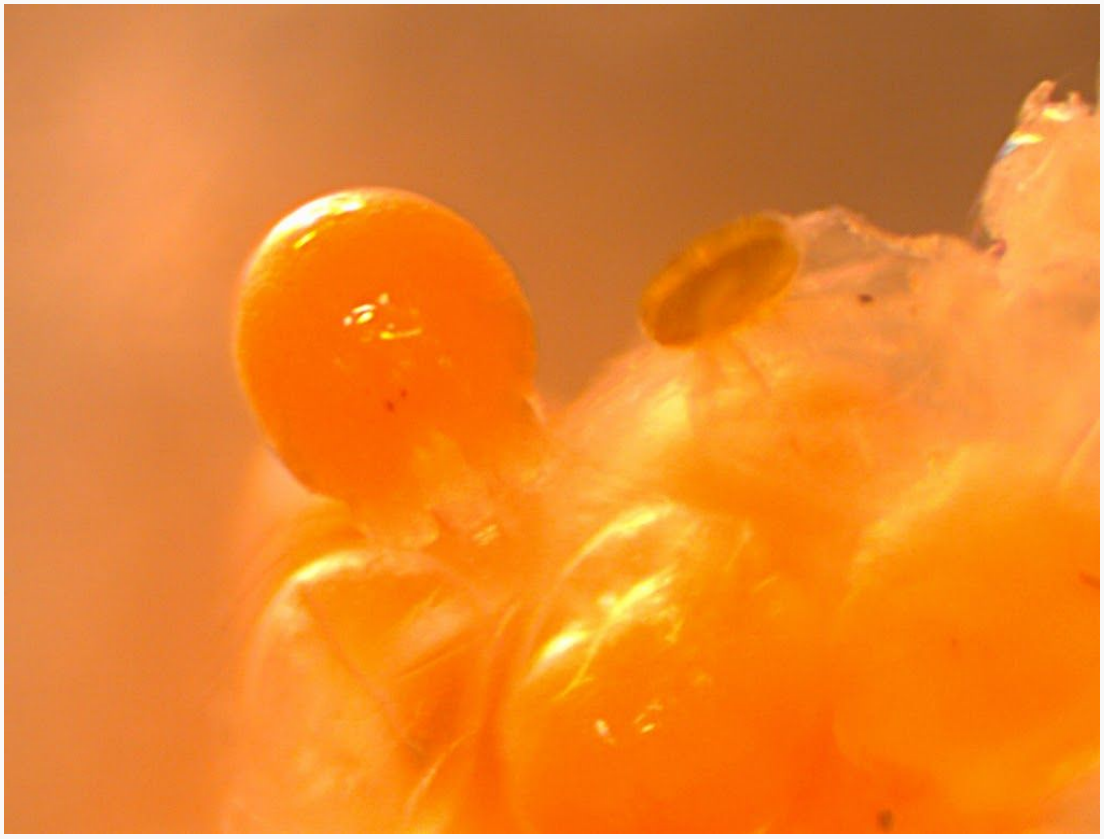
Sea Spider development photos (order of development: egg; Instar 1; Instar 2; Instar 3; adult)



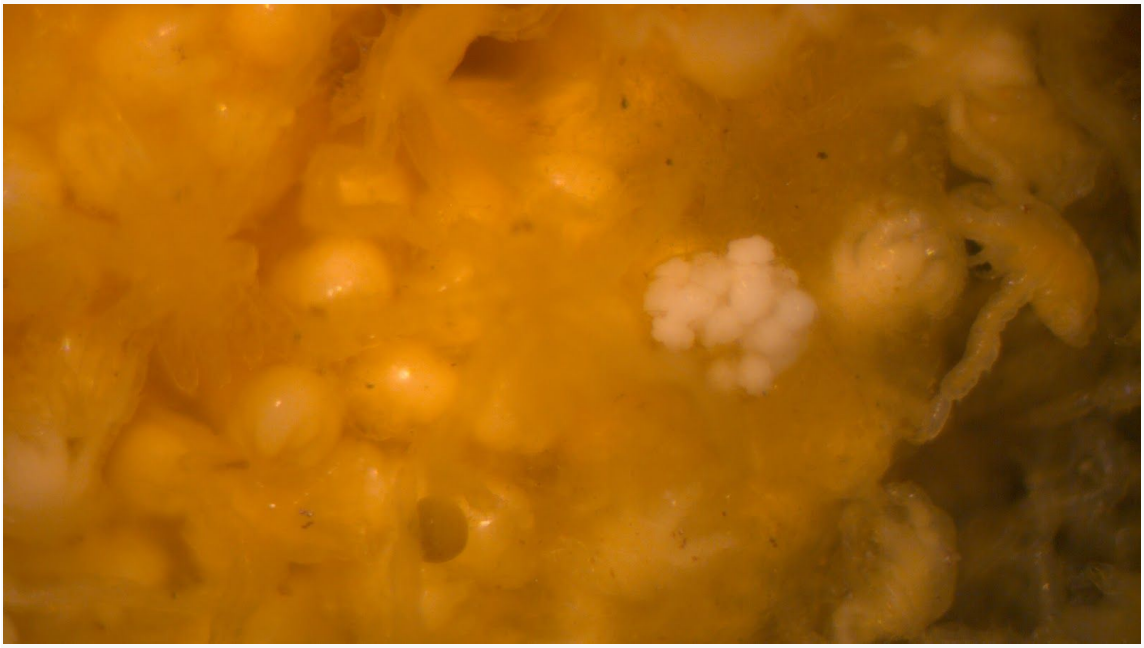
Late stage of sea spider development-Instar 3. Crary Lab, McMurdo Station, Antarctica. (Photo by Aaron Toh, 2019)



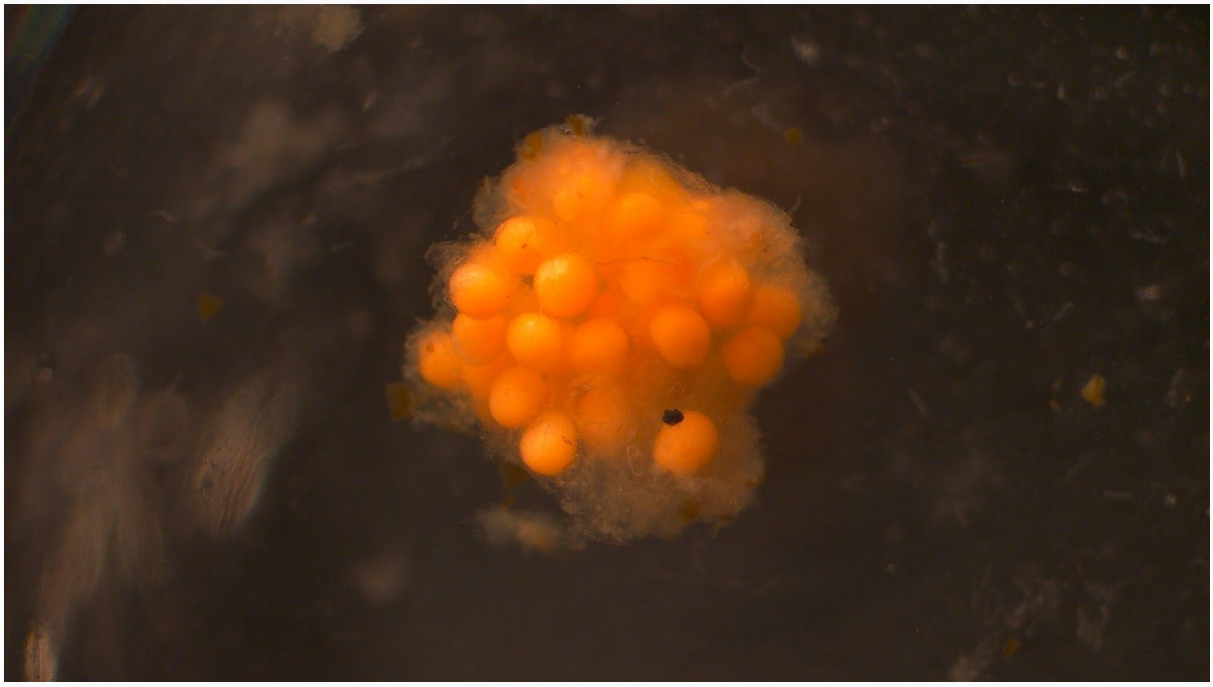
Sea spider (*Ammothea*) eggs. Crary Lab, McMurdo Station, Antarctica (Photo by Aaron Toh, 2019)



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)



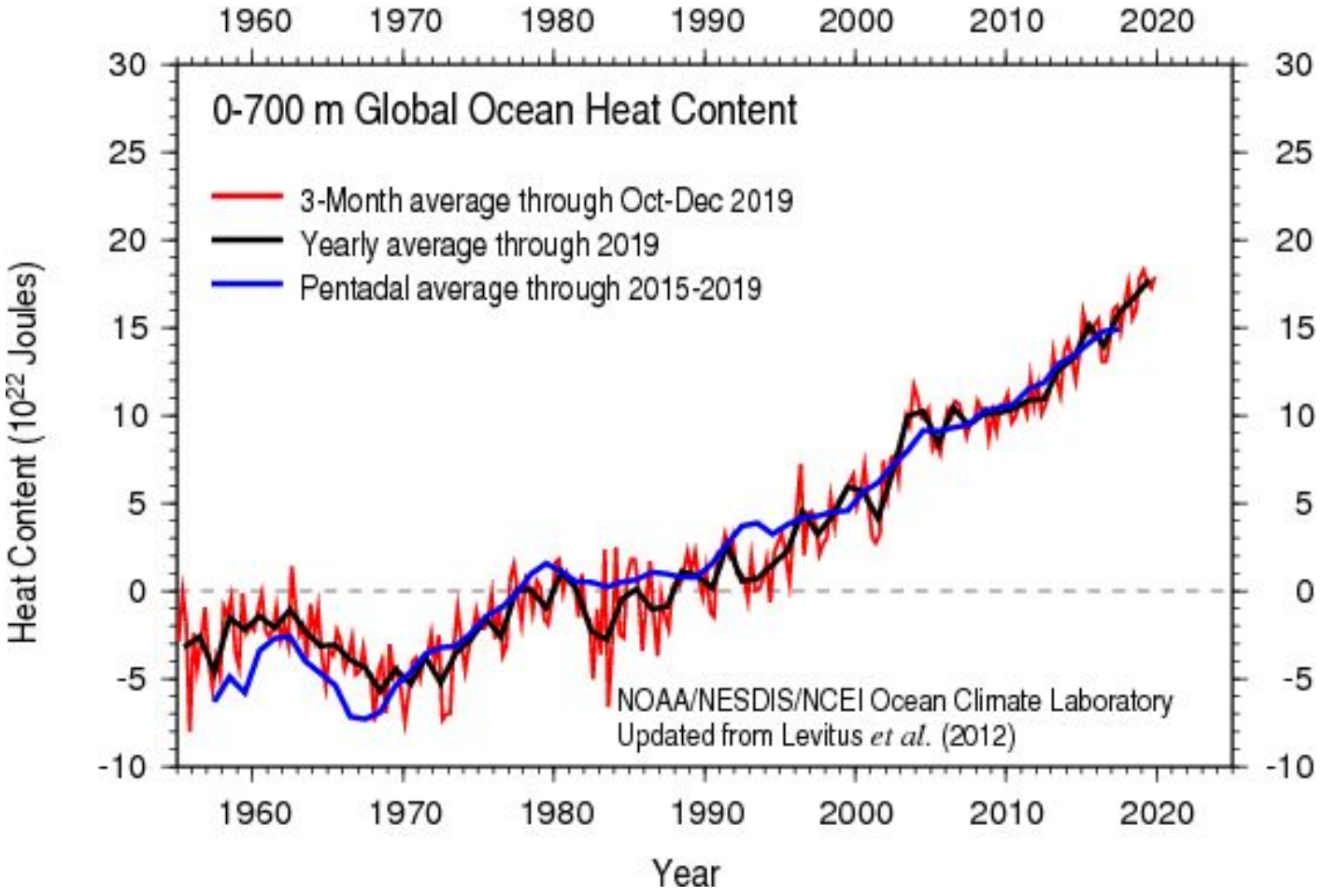
Sea Spider growth-Instar 2 Photo by Aaron Toh, Crary Lab, McMurdo Station, Antarctica 2019



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

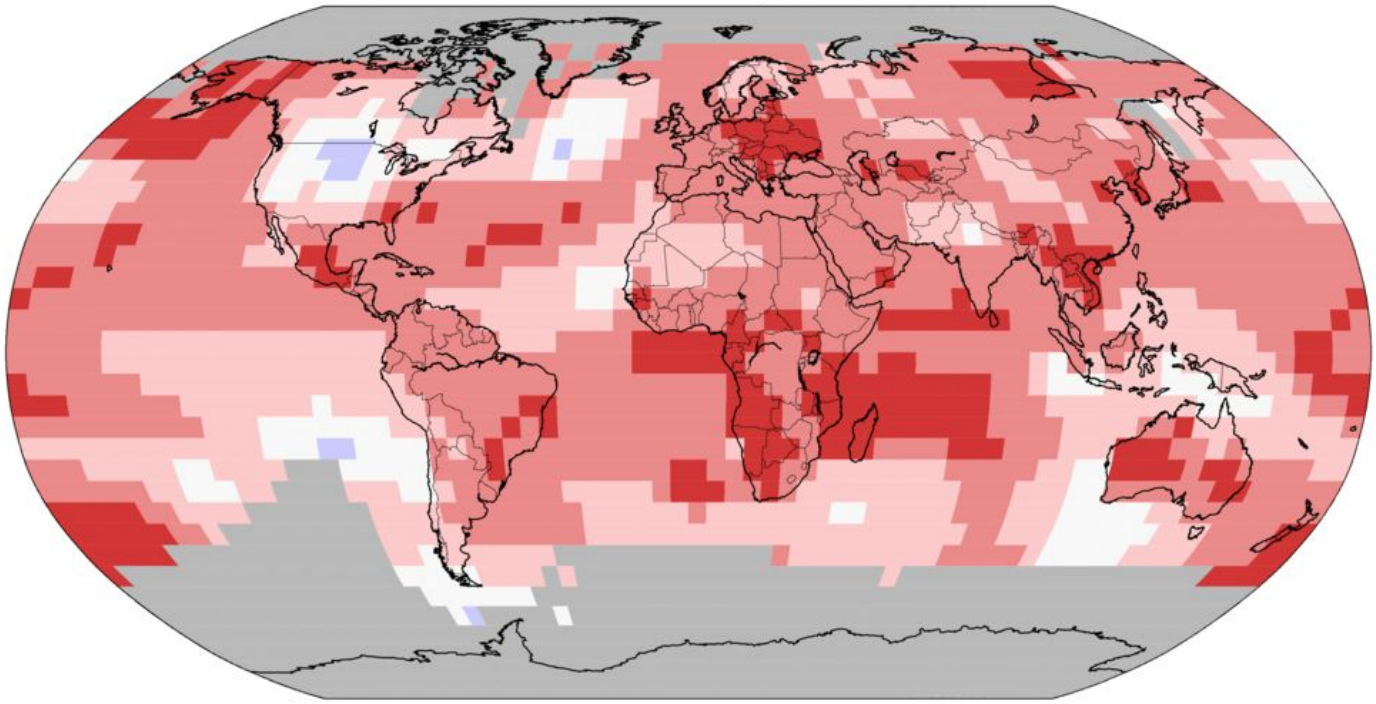


https://www.nodc.noaa.gov/OC5/3M_HEAT_CONTENT/

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