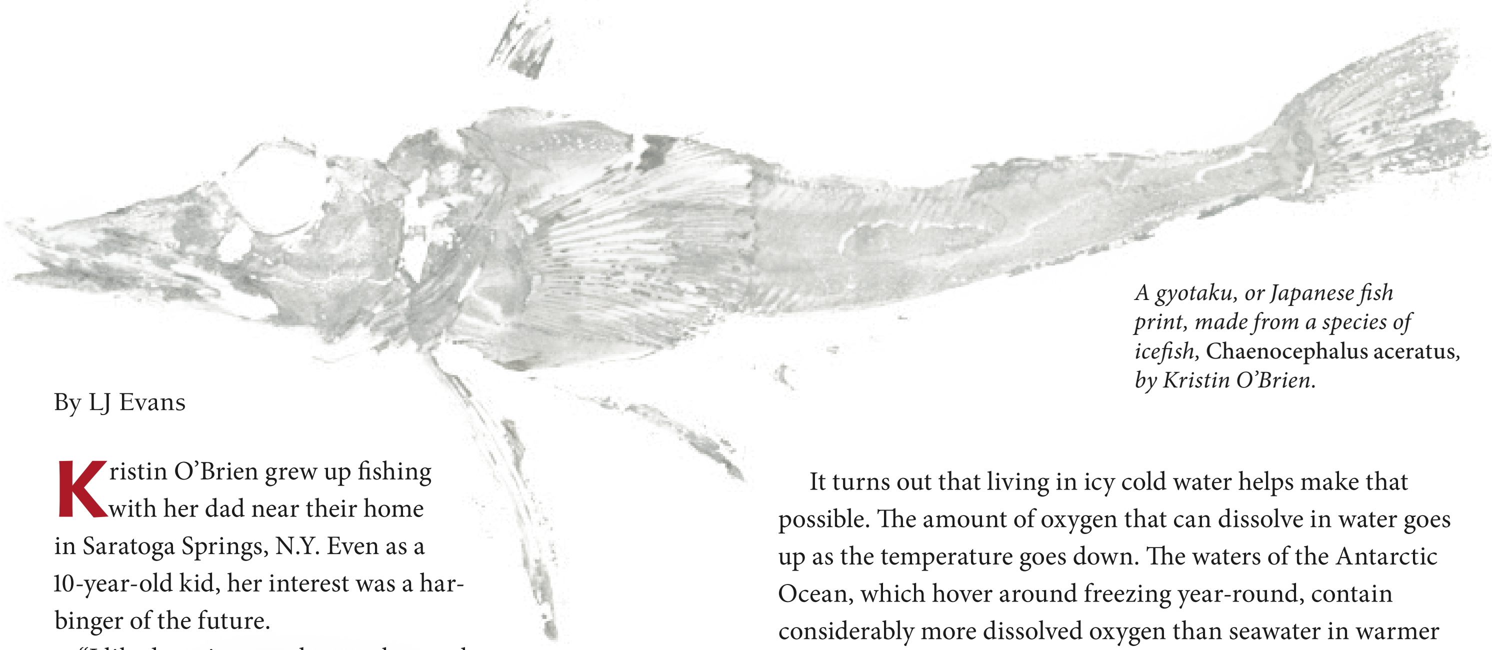
Blood may be thicker than water but it isn’t always

Photo by Kristin O’Brien.

Photo by Uwe Kils.

Photo by Reinhart Piuk.



A gyotaku, or Japanese fish print, made from a species of icefish, Chaenocephalus aceratus, *by Kristin O'Brien.*

By LJ Evans

Kristin O'Brien grew up fishing with her dad near their home in Saratoga Springs, N.Y. Even as a 10-year-old kid, her interest was a harbinger of the future.

"I liked cutting out the guts better than I liked fishing," she says with a chuckle.

O'Brien still examines fish innards, but in a completely different setting. In laboratories at UAF and in Antarctica she studies the peculiar icefish — family Channichthyidae, suborder Notothenioidei — the only vertebrates in the world whose blood is milky white.

"Icefish are a wondrous physiological phenomenon," O'Brien says. Biologists have been fascinated with icefish since early British whalers discovered them in the Antarctic Ocean in the late 1800s; Norwegian scientist Johan Ruud first described them in the scientific literature more than 50 years ago.

Icefish occupy the coldest marine environment on earth, constantly near the freezing temperature of seawater. Icefish and their relatives are by far the most plentiful fish in the waters surrounding Antarctica.

In most animals, hemoglobin in the blood transports oxygen from the lungs (or in fish, from the gills) to tissues in the body. Muscles and organs need oxygen to convert energy stored in food into the chemical energy they can use. Not having hemoglobin means that the total oxygen-carrying capacity of icefish blood is only about 10 percent that of red-blooded fishes. Icefish adapted by developing special physiological processes to survive without hemoglobin.

It turns out that living in icy cold water helps make that possible. The amount of oxygen that can dissolve in water goes up as the temperature goes down. The waters of the Antarctic Ocean, which hover around freezing year-round, contain considerably more dissolved oxygen than seawater in warmer climes. This means there is more oxygen available for icefish gills to extract and transfer into their blood. It also means their blood plasma — composed mostly of water — is able to transport more oxygen. In addition, icefish have adapted to the lack of hemoglobin by having larger hearts, more blood and bigger blood vessels than similar, red-blooded species. In organs that need a lot of oxygen, such as the retina of the eye, they have more blood vessels per square inch.

Another peculiarity of icefish is that some species have no myoglobin in their heart muscle. Myoglobin, a protein with some similarities to hemoglobin, binds and stores oxygen within muscle tissue. Myoglobin also contains iron and is the molecule responsible for making muscles red.

Hemoglobin and myoglobin both bind an atom of iron at the core of the protein. Iron is a highly reactive element that, if too abundant and running around loose, promotes formation of free radicals. In living organisms free radicals can be associated with cell destruction, as is seen in Alzheimer's and Parkinson's disease. O'Brien and her co-principal investigator, Lisa Crockett of Ohio University, are comparing icefish with fish that are closely related but have red blood.

"We are building knowledge concerning a group of animals that have evolved in an extreme environment," Lisa Crockett

Photo by Steve Untracht.

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Photo by Kristin O'Brien.

said in a phone interview. "We want to know if there is an advantage in not having hemoglobin as far as being a protective mechanism against oxidative stress [the effects of free radicals]."

How do icefish get away with these radical biochemical adaptations? O'Brien and her colleagues will continue to study icefish for information that might shed more light on how these systems work in other animals.

"It's like summer camp for scientists."

It may be a long shot, but basic research has led to major discoveries in medicine in the past, Crockett points out.

"They weren't looking for an antibiotic when they discovered penicillin," she says.

Working in the Antarctic: It isn't for everyone

Live icefish don't travel well. They're too fragile, O'Brien says. She and Crockett organize field trips to Antarctica every other year with their team of researchers and grad students to catch the bottom-dwelling icefish and conduct their studies.

"It's so much fun. It's like summer camp for scientists," O'Brien laughs, a hint of glee in her blue eyes. When she is on campus at UAF, the 44-year-old associate professor of biology spends most of her time writing, teaching, and mentoring graduate and undergraduate students. She rarely gets to work in her own lab.

When the team is "on the ice" in Antarctica the situation is vastly different, involving many days of long hours, sometimes round-the-clock, to catch the fish and conduct experiments.

O'Brien and her colleagues head for the tip of South America with the support of grants from the National Science Foundation. They stage for departure in Punta Arenas, Chile.

An NSF contractor stockpiles supplies shipped south for Antarctic field trips. There is a wall in the warehouse where a sample of practically every item of clothing you need to be comfortable in a bitterly cold place is numbered and tacked up on display. Wool socks and balaclavas, neoprene gloves and polypropylene turtlenecks, down parkas, hardhats and heavy-duty insulated boots — everything hangs on that wall.

"You go up to a counter and tell an attendant how many of what you need and the items are checked out to you, like library books," O'Brien says. When the researchers come back from a field trip, they return the items to be cleaned, reconditioned and readied to go out with the next group of scientists or support staff.

"You can pack a bag with just your underwear" to go on a research trip to Antarctica, O'Brien says. Most people like to have at least some of their own clothes, and at the research station where O'Brien works there's a little store where you can buy toiletries. But otherwise workers pick up all their gear in Chile before they leave.

When weather and the seas allow, it takes about four and a half days aboard the 230-foot U.S. Antarctic Research Supply Vessel *Laurence M. Gould* to make the trip from Punta Arenas,

◀ *Top to bottom, left to right on previous spread: The ARSV* Laurence M. Gould *at the dock at Palmer Station, Antarctica. A juvenile icefish. Kristin O'Brien and Irina Mueller unload fish to transfer to the Palmer Station aquarium. O'Brien and Devin Devor of Ohio University draw blood from a red-blooded notothenoid. Lisa Crockett extracts icefish blood. Vials of icefish blood (right) and blood from a related, red-blooded fish.*

through the Straits of Magellan and across Drake Passage to Palmer Station.

"The trip is always exciting, regardless of the sea state," O'Brien said in a College of Natural Science and Mathematics newsletter last year. "The four-plus days provide us with an opportunity to finalize research plans and get to know the other scientists and support crew on board, many of whom have become good friends over the years."

Palmer Station, owned and operated by the United States since 1968, is on Anvers Island, off the western shore of the Antarctic Peninsula. The station's main building houses labs, dorms, a dining room, kitchen and offices; other structures hold generators, boats, more dorms and labs, a lounge and even a small gym. About 50 researchers and support crew can be accommodated there. When the ARSV *Gould* arrives, everyone piles out to welcome the new arrivals, put down the gangway and unload the ship. There might be several different research groups at the station at any one time, with scientists and graduate students collecting data on projects as diverse as the ecosystems of Antarctic fjords to a species of worm that lives strictly in whale carcasses.

"We are always there in May and June," O'Brien says. "That's the beginning of summer in Alaska but leading right into the Antarctic winter in the Southern Hemisphere."

The day O'Brien's team arrived at Palmer last year, they split into two groups. The less seaworthy among the group stayed "on station," unpacking and setting up the lab. The more avid fisher folk, O'Brien among them, departed on the *Gould* for a four-day fishing trip.

"We fish 24 hours a day in two shifts of 12 hours each," O'Brien says. It takes 20 minutes for a net to reach the bottom, they trawl for 20 minutes, and then it takes another 20 minutes to bring the net back aboard.

"We fish in an area where we know the bottom is smooth [so the net won't tangle]. We run a pass in that area, and then we turn around and go back."

Frantic activity ensues when the net's contents are disgorged on deck. Scientists and crew transfer the fish into tanks filled with circulating cold seawater, and return any unwanted or invertebrate species to the water.

On average they fish for 72 hours — about six shifts — or until the tanks are full. Then they head back to the station to process the catch.

Once at Palmer, a crane operator slings the tanks from the ship's deck to the dock. O'Brien and her crew scoop up the fish with nets and move them to seawater tanks inside the lab or on a deck outside.

That's when the real work begins. Over subsequent days, the scientists remove fish from the tanks for study. Some are anesthetized and their blood collected, some are sacrificed for organ or tissue samples. Though a lot of the lab work is done at Palmer, some tissue samples are frozen for analysis at UAF or other sites.

Occasionally, once all the sampling is done, an icefish might end up as the main course at dinner.

The ARSV Laurence M. Gould *at Palmer Station. The* LMG *is the primary means of transporting cargo and personnel between Palmer Station and Punta Arenas, Chile.* Photo by Kurtis Burmeister, National Science Foundation.

Chaenocephalus aceratus. Photo by Bill Baker.

"They don't taste like much of anything. They need lots of butter and garlic!" says O'Brien.

The bland flavor of white-fleshed fish is related to the lack of myoglobin, O'Brien says. "That richer taste when you're eating meat comes partly from the presence of myoglobin."

"[The fish aren't] warm and fuzzy, but understanding how climate change will affect them is no less important."

Don't forget anything

Conducting research at such a remote and difficult location presents immense challenges. Enormous planning goes into every detail.

"If you discover when you get there, 'Oh, I forgot the hydrochloric acid' — guess what? You don't get any hydrochloric acid!" O'Brien says. "It can be a show-stopper. It can end your field season that you've spent years preparing for."

In 2009 her team discovered that the wrong pumps for circulating seawater in the tanks had been delivered to Palmer Station.

"We found out after the ship had already left the dock [in Punta Arenas]." Fortunately, the support staff at all the NSF-funded Antarctic stations are highly skilled, highly trained, resourceful individuals, O'Brien notes.

"With their help you can repair things or come up with an alternative," she says. When the wrong pumps were delivered, the support crew was able to adapt some older pumps already at the station.

If what they need is available in Punta Arenas and the ARSV *Gould* is at the dock there, it might be possible to get the item in only four and a half days.

"But the problem is, the ship doesn't always go. It could be halfway into your field season before [the item] arrives," O'Brien says.

Sometimes other research groups working at Palmer Station have equipment or chemicals that can be borrowed, kind of like borrowing a cup of sugar from your neighbor. O'Brien can ask to use something from that team's stash, then replace it later or compensate with something else.

One way or another, the work gets done.

Rising temperatures, commercial fishing bode ill for Antarctic fishes

A major project for the 2011 field trip was to try to understand why icefish respond so poorly to rising water temperatures. Earlier research already confirmed the critical thermal maximum for icefish — the temperature at which they start to go belly up — is 55.4 F (13 C), whereas for their red-blooded brethren it is 60.8 F (16 C). For comparison, fish species from more temperate climates can survive temperatures of between 60.8 – 86 F (20 – 30 C).

To the surprise of O'Brien and her team, the reduced oxygen-carrying capacity of their blood is not the reason icefish are more sensitive to elevations in temperature. Researchers are still trying to figure it out.

Regardless of the mechanism, sensitivity to rising water temperatures is worrisome because western Antarctic surface waters are one of the most rapidly warming regions on earth, O'Brien says. Studies show that the upper water column temperature has increased by 1.8 degrees F (1 degree C) since 1950. This matters because the creatures that live in the ocean there are adapted to very narrow temperature ranges.

Photo by Devin Devor.

Kristin O'Brien, Chicago high school teacher Paula Dell and Lisa Crockett take a break while out fishing on the LMG.

"We don't know how they will adjust to the increase in temperature," O'Brien says. Her team and other researchers have been able to do tests on just a few species, and of those, only adults. "We don't know what this will mean to reproduction or to the larval stages of these animals."

Another reason for urgency is an increase in commercial fishing activity, according to Crockett. Because of overfishing in the world's oceans, fishermen are going after species they haven't targeted before. Even in some areas of Antarctica, fish populations have been decimated.

"It's important that we continue to learn about the organisms that we co-inhabit the planet with," Crockett says. She compared the situation with the Antarctic fishes to that of the polar bear.

"[The fish aren't] warm and fuzzy, but understanding how climate change will affect them is no less important. In this case we're not talking about a resource in the sense of fish meat. It's a resource for scientific knowledge and gaining better understanding of how animals work."

Academic genealogy

The path that led O'Brien to a career studying Antarctic fish at UAF began with her fishing trips with her dad, led her through a BS in zoology at Duke University, and after several more twists and turns — including a two-year stint as a National Marine Fisheries Service fisheries observer in Alaska — took her to doctoral studies at the University of Maine, in Bruce Sidell's laboratory.

She had heard Sidell give a talk just after she graduated from Duke.

"His research on lipid metabolism of Antarctic fishes was fascinating, but equally enthralling were his photographs of the Antarctic and his clear passion for the place," O'Brien says. A few months later she applied to study in Sidell's lab. It was the start of a 17-year collaboration and friendship.

In a 2009 interview about icefish in *The Antarctic Sun*, an online publication of the U.S. Antarctic Program, Sidell said, "I just want to figure out how these critters work. We get a chance to ask some questions with these [animals] that you can't ask with any other animals on the planet."

"He had a big influence on my life," O'Brien says. "He was my academic father in every sense of the word." She says Sidell often mentioned that one of his greatest pleasures as a professor was mentoring graduate students.

Sidell asked O'Brien to collaborate on an NSF grant while she was a postdoctoral fellow at the University of Colorado, which launched her career working in the Antarctic. While she was on her way to her faculty position at UAF, Sidell asked if she'd write an icefish research proposal with him.

"I may have paused as long as 10 seconds before replying with a resounding 'YES!'" she says. O'Brien calls Crockett, who was also a graduate student under Sidell, her "academic sister."

"When you work that closely with a person a lot rubs off," Crockett says. "Bruce's greatest influence on me has been probably more about life than about science. I think both Kristin and I try to emulate some of those qualities that were so superlative in Bruce. He knew how to get right to the heart of things."

Sidell's academic lineage continues through the students O'Brien supervises at UAF. Her most recent success story is Irina Mueller, initially an exchange student from Germany who came back for advanced work in O'Brien's lab. Mueller was awarded a PhD at commencement last May but couldn't attend the ceremonies. She was already at Palmer Station, preparing to spend the Antarctic winter working with a scientist from

Northeastern University researching bone development in icefish.

"I started working in Kristin's lab during my [2005 – 2006] exchange year to supplement my income," Mueller said in an email interview. When the offer to be a grad student came from O'Brien and included the opportunity to spend the 2011 season in Antarctica, she leapt at the chance.

"By the time I signed on as her PhD student we knew each others' personalities, working approaches and expectations, which made my years as a student in her lab a very positive experience."

Pursuit of a life in science

O'Brien went "down to the ice" for research expeditions in Antarctica twice while in graduate school, and has returned as an NSF grantee four times since. On all but the 2011 expedition, Sidell was a major force.

Bruce Sidell died in February 2011, after a lengthy bout with cancer. A remembrance by colleagues and friends noted that "Bruce's approach to science … not only helped to shape the career approaches of his many graduate students but also served as an exemplar … of how best to pursue a life in science."

Sitting in her office about a year after Sidell's death, O'Brien chokes up as she tries to explain how important his influence has been on how she goes about the business of being a scientist. Sidell was so respected by other Antarctic researchers that they gave his name to a geographic feature in the region where he did most of his work. After lengthy discussion they chose an outcropping on the western shore of Brabent Island.

"One of the most memorable moments during the [2011] field season was our visit to Sidell Spur," O'Brien says. "The day began as a cloudy one, but as we approached and the sun shone through, illuminating the face of the spur, I couldn't help but think that Bruce was with us at that moment."

LJ Evans is a writer and editor for UAF Marketing and Communications.

Learn more about Kristin O'Brien's icefish research and her work with Chicago high school students and their teacher at **www.uaf.edu/aurora/**.

Sidell Spur, in Antarctica, named to honor Bruce Sidell's many years of Antarctic research. Photo by Kristin O'Brien.

UAF alumna in this story: Irina Mueller, '12