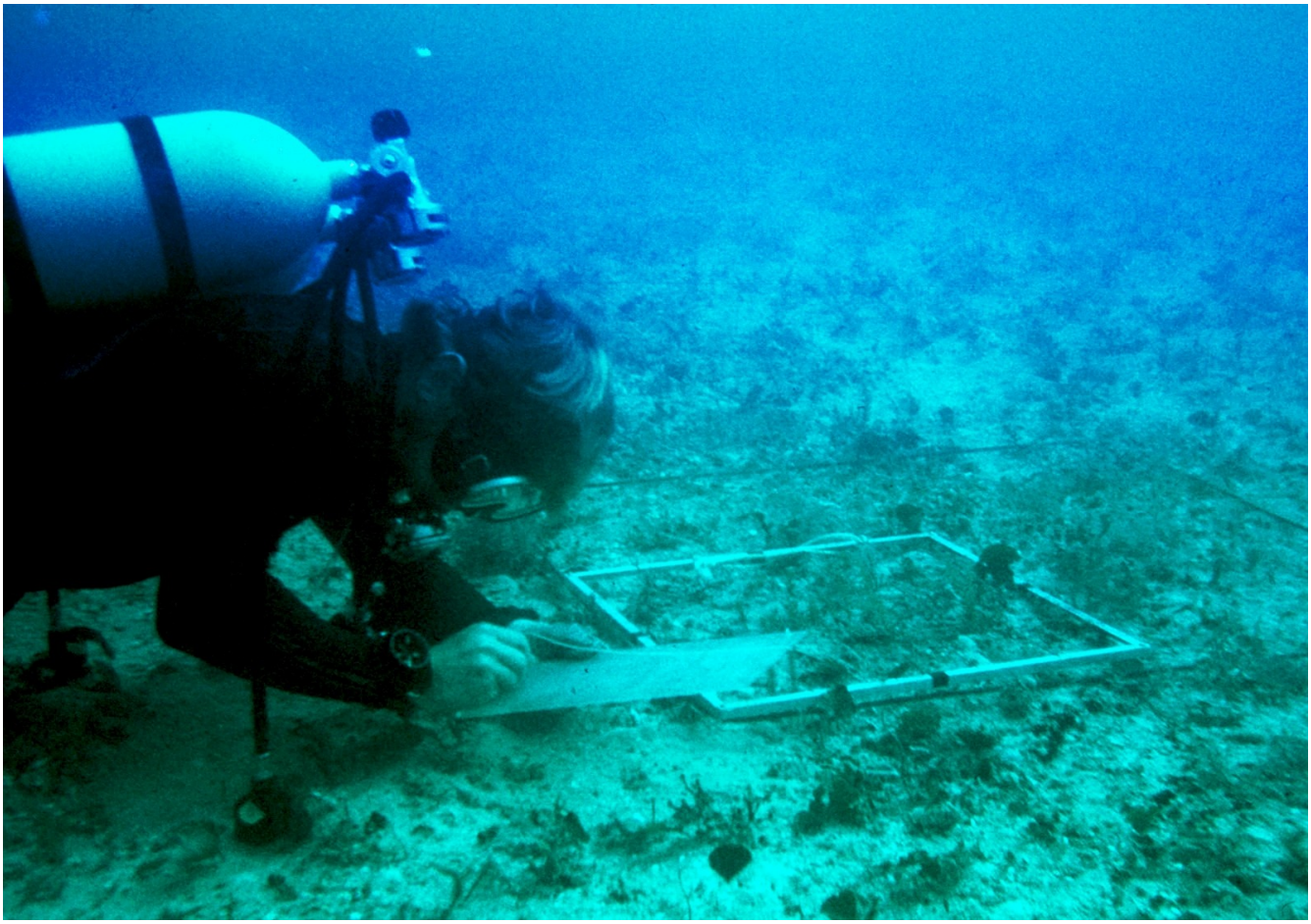

Photo Art Dahl

Underwater studies in the Caribbean

La Chalupa underwater laboratory

I had been in charge of the Marine Biology Section of Puerto Rico Nuclear Center (PRNC) for a few months when I heard about an underwater marine laboratory operating on the west coast of Puerto Rico. My curiosity immediately awakened because it sounded like an ideal opportunity to combine my two ambitions – prolonged diving and research underwater without interruptions due to daily surfacing.

I did not know Puerto Rico International Undersea Laboratory (PRINUL) or its people until then. Because I was busy getting ready for a six week trip to Bikini Atoll to collect radioactive samples on

board our research vessel RV PALUMBO, I did not have an opportunity to visit PRINUL's operation people. So I forgot the whole thing for a while.

After I came back from the Marshall Islands, to my surprise, I received an invitation to attend the second dive mission in PRINUL's underwater laboratory La Chalupa. At the same time, they wanted another scientist from my laboratory to a team of four aquanauts. I was elated by this unbelievable opportunity! I talked to our aquatic chemist, John Montgomery, about living for two weeks underwater to make a study whatever he wanted. He, too, jumped on this exciting chance.

The habitat was designed by Ian Koblick and build by Berry Submarine Construction. PRINUL's marine biology missions were associated with NOAA (National Oceanographic and Atmospheric Administration), while the Undersea Science and Technology missions were part of the MUS&T program. After the 10 NOAA and MU&T missions ended between in March 1974, the Marine Sciences Department of the University of Puerto Rico used the habitat for two additional dive missions.

The construction and operation of La Chalupa

La Chalupa received fresh air, potable water, electricity, and air conditioning from the Support Vessel on the surface. Inside the barge's steel hull were two steel pressure chambers of 6 meters long and 2,41 meters in diameter. Between cylinders was a non-pressurized 3x10m Subport space with a 1,8 x 2,4 meters diving opening to the ocean. The surface of water stayed about 10 cm above the floor. A steel crate bridge allowed the Aquanauts to walk between the Instrument and the Living Compartments without wetting their feet.

Both cylinders had 104-centimeter diameter portholes, which provided a spectacular view of the surrounding ocean. Both compartments had pressure doors that opened in different directions. The living compartment's door opened inwards which allowed the crew to stay there during the decompression. The instrument cylinder's hatch opened to the Subport to let the equipment's servicing while the diving crew was in the decompression.

PRINUL site was close to the extensive El Negro reef, where most of the missions took place. I had dived for years on the north section of El Negro, but its southern parts where PRINUL missions took place were unknown to me but quite similar.

The research vessel R/V PALUMBO of the Marine Biology program of PRNC towed La Chalupa and the Support vessel to and from sites in the reef area. Once they were above the intended location, PRINUL's diving team opened the valves to trim tanks and two ballast tanks. I addition to the fillable tanks, the barge had 75 tons of concrete ballast. As the ballast tanks filled with seawater, La Chalupa sank slowly on the sandy bottom next to the reef.

On top of the barge were two white compression chambers for emergencies. People could enter them from the inside of the habitat. If needed in an emergence, they could be unbolted from the barge and transported to land.

Figure 2. La Chalupa and its support vessel in PRINUL harbor.

My first diving mission

During each mission, the crew consisted of four scientists and a service engineer. In my first mission, the scientists were chemist John Montgomery from PRNC, the marine phycologist Art Dahl from the Smithsonian Institute, marine biologist Frank Torres from the Department of Natural Resources of Puerto Rico, and myself. Mike Dugan was our maintenance and service engineer.

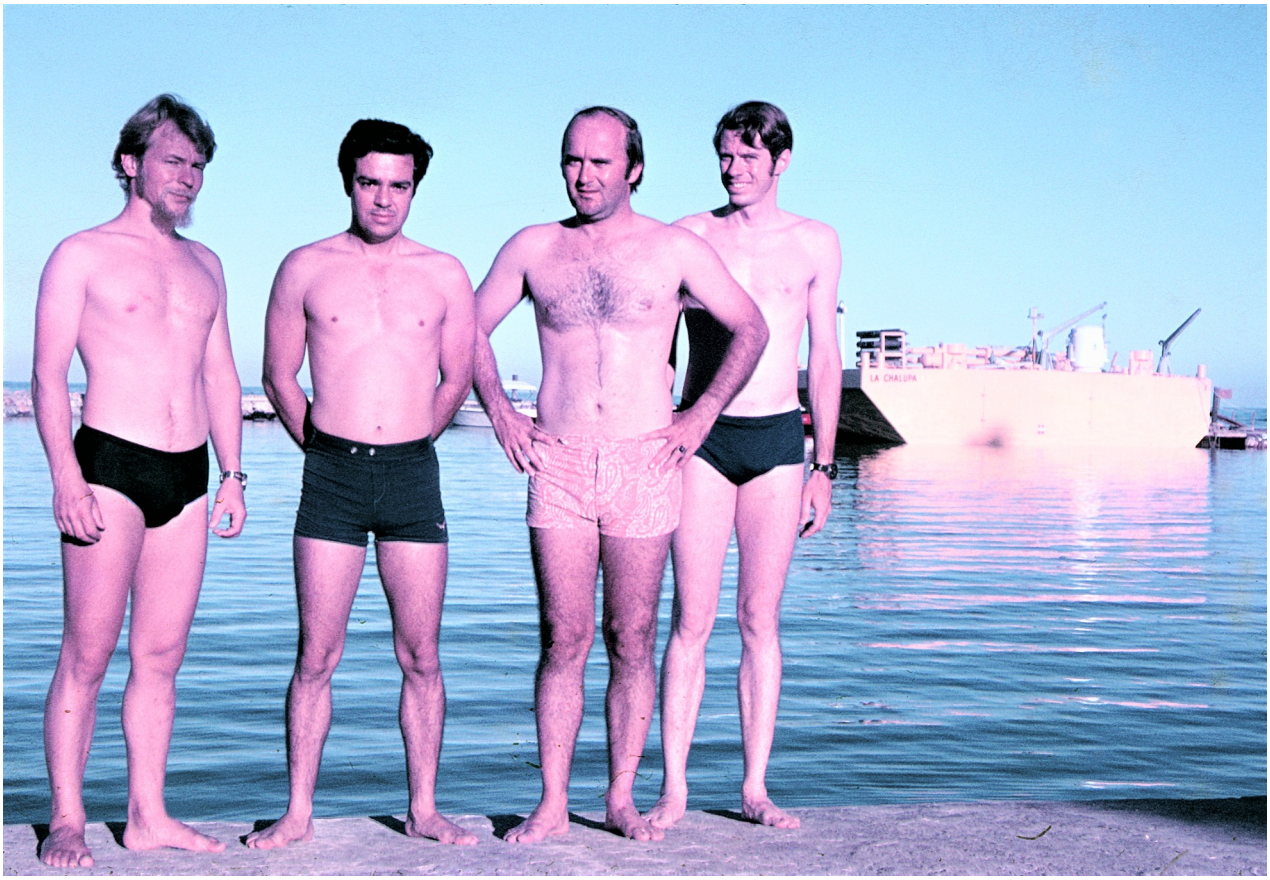

Figure 2. Seppo Kolehmainen, Frank Torres, John Montgomery, and Art Dahl at PRINUL base after morning's physical training .

Before settling in the habitat, we had a week-long training period on La Chalupa's equipment and facilities. Each morning we also had physical exercises that included running and swimming. At the end of the training week, the medical doctor of PRINUL gave us an extensive medical examination. Besides the usual questionnaires, blood and urine tests, we also were taken X-rays of the long bones in the arms and the legs. The X-rays were controls for potential bone cell mortality from saturation diving.

Blood circulation in the thin vessel of long bones is slow, and even in otherwise sufficient decompression, nitrogen bubbles may block tiny blood vessels. Lack of oxygen kills bone cells and makes them lose their strength and elasticity. The dead bone area has only calcium carbonate, which has caused Navy divers to suffer broken legs due to brittle bones in minor stumbles.

Unfortunately, there were no more medical testing at PRINUL after our initial medical checks due to a lack of funds. So I never learned whether the saturation diving had left any changes in my long bones.

Going to La Chalupa in a storm

Our diving mission started on the 22nd of December 1972 during a cold front. A fierce storm delayed the towing of La Chalupa to the site. Most of the year, winds on the West Coast of Puerto Rico are moderate. In the winter, great depressions brought from Northern Atlantic brought rain and storms to the Caribbean. One such storm raised havoc on our coast and our crew had to wait on the shore until the submerging team had placed the habitat on the bottom at the diving site.

Figure 3. Ready to submerge.

Mike Dugan had already gone to the site to help the PRNUL team lower La Chalupa to 18 meters on a sandy bottom. The scientific crew was still on land, waiting for the storm to subside.

The day was turning already to the evening when we finally were heading towards the site in a motorboat. Upon arrival there, we saw the Life Support Vessel bouncing up and down in over 3-meter waves. We quickly tossed our diving gear on and dropped ourselves into the water. Usually, the Caribbean water was crystal clear, with lateral visibility of 30 meters, but now the turbidity had lowered it to a few meters. I swam above La Chalupa, whose towering figure I barely spotted

underneath. The barge was bright yellow, but it looked more like a grayish boulder through the turbid water at dusk.

Hurriedly I dove down and swam under the barge towards the diving port, where its lights illuminated the sandy bottom white. Even on the bottom, the wave action was so heavy that it stirred up fine sand.

I entered the dive opening and climbed up to the crating floor of the Subport. After placing my diving gear on the floor, I noticed an irritating sensation in my ears. Looking around, I saw that the water level in the subport was going up and down. It caused the air pressure to change accordingly. High waves on the surface produced a pumping phenomenon that caused water to rise and fall 30 cm in the subport. As a result, the fluctuating air pressure made my eardrums pop unpleasantly every few seconds. So much dramatics upon arriving at La Chalupa made me worry about whether the life in La Chalupa would feel comfortable after all.

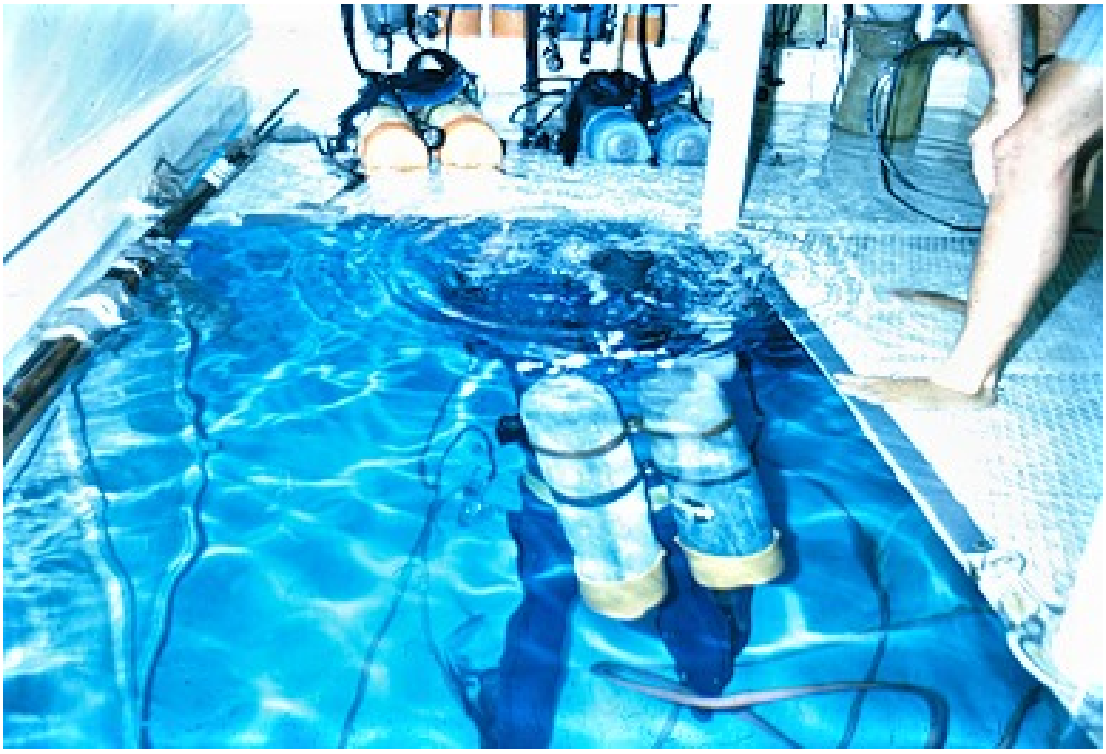

Figure 4. The diving opening was 1,2 m x 1,5 m, and it was above the sandy bottom. The floor was 10 cm below the surface to make it easier to get out of water.

However, I shook such thoughts off quickly, took my Neoprene diving jacket off, and put it on a hangar. Soon all other team members had climbed through the dive opening and donned their gear. They also complained about the discomforting popping of their ears and noticed the water level fluctuation in the subport.

When other members of my team had undressed their diving suits, we all entered the living compartment. As soon as we closed the pressure door, the unpleasant popping of years stopped, and the living compartment's conditions felt fine.

We spent the first night customizing our new dwelling's conditions and getting to know our companions better. Although we had already spent one week training period together, there was not much time for socializing. From the team members, I previously had known only my colleague John before. As we spend two weeks together in the cramped living space, we decided without disagreements which bunk each one would take and where to keep one's belongings.

Figure 5. Water beds were comfortable and their mattresses served as emergency water reservoirs. Art (on the right) is having a conversation with John.

In the living compartment there were four water beds and one small table. The scientists slept on the beds and our service engineer Mike on the floor of the instrument compartment. Neither compartment had any room for another bed.

After the first night, the storm had subsided, and the visibility of seawater returned to normal. The Caribbean was again peacefully calm.

Living in the habitat

We had to make a few adjustments to living in Neptune's Kingdom. Inside the habitat, we found that swimming trunks were the most practical attire. Although the temperature was pleasant, our atmosphere had about 90% humidity. We took no wet cloths or equipment inside the cylinders to prevent any higher humidity but kept our dive gear and suits in the subport.

We dove several hours every day with SCUBA gear that had two tanks. At 18 meters, the tanks lasted less than two hours, so they had to be filled two or three times a day.

The life underwater and in the habitat was relatively comfortable, and it gave plenty of time to conduct extensive studies *in situ.* Seeing the same area from day to day for two weeks allowed noticing even small changes. I found it engaging to witness species interactions and their symbiotic relationships. I enjoyed watching different species of fish in their habitat and how they guarded it. Daily, I stopped for a while to watch a cleaning fish in their station to pick parasites from parrot fish.

Although there was a toilet bowl in the subport, it was in service only once for a particular reason. Someone had used the toilet and flushed it. The solid proceedings disappeared to the sea, but immediately a stink permeated everywhere in the habitat, and it took forever to subside. We had been only a short time in La Chalupa, so the partial pressure of oxygen was three times higher than on the surface. Since we used pure oxygen during the decompression and its prolonged exposure is toxic, our fresh air exchange was kept minimal. Our breathing reduced the oxygen level in the atmosphere slowly. Thus we had to maintain the air exchange at a low level. Once the oxygen had sunk to 7%, we increased the ventilation rate.

After this smelly gas attack, we unanimously agreed to swim to the top of the barge to relieve ourselves by holding on to the corner post and bending over the reeling.

The instrument compartment had a new gadget, a microwave oven that none of us had seen before. Next to it was a freezer chest that contained our gourmet meals, which had come from a Miami restaurant. Heated by microwaves, they tasted just as delicious as advertised.

The freezer suffered external damage from the 3-bar air pressure, which caused the Styrofoam insulation to collapse partly and twist the lid. It stayed sufficiently closed by duct tape to keep the contents frozen.

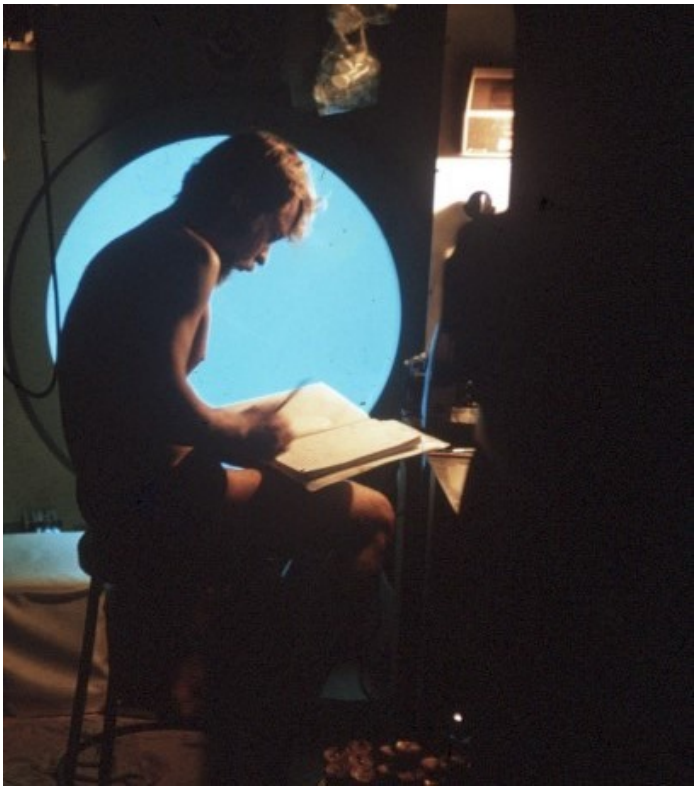

Figure 6. The living compartment had only one tiny table for writing (photo Art Dahl).

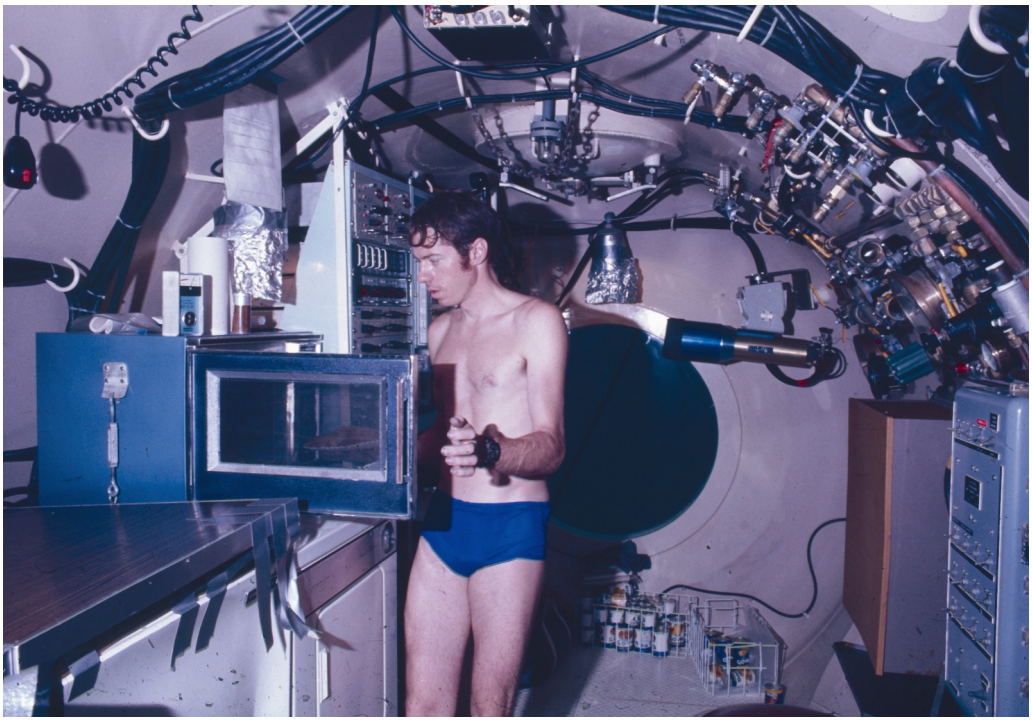

Figure 7. Art cooked our food in the equipment compartment with a microwave oven. On lower left is our freezer that suffered insulation damage in high air pressure.

Figure 8. When we had no table for eating, we ate by sitting on the floor (photo Art Dahl).

After the dives, we rinsed the salt from the skin by a quick shower and dried ourselves in the subport. Even though the air-conditioning reduced the humidity, we had to protect our ears from infections. We did it by rinsing the outer ear canal with a disinfecting solution.

Figure 9. After dives of the day, we treated our ears with a disinfectant to avoid ear infections.

It wasn't until the first afternoon that we realized a strange change in our voices. The high pressure made our speaking sound like high-pitched Mickey Mouse talk. After we noticed that, we got used to it and accepted it as expected in that environment.

Our team had good cooperation, and I don't remember that we had any disagreements despite differences in personalities.

I found Art an engaging member for acting politely and practicing the Bahai Faith. Frank was a modest and quiet Puerto Rican and dedicated to his research. John was a typical Irish fellow, an honest friend of mine for two years, and my colleague at PRNC. Mike was Davy Crocket -type Tennessean who had lived among the Hillbillies and had some daring jobs as a diver.

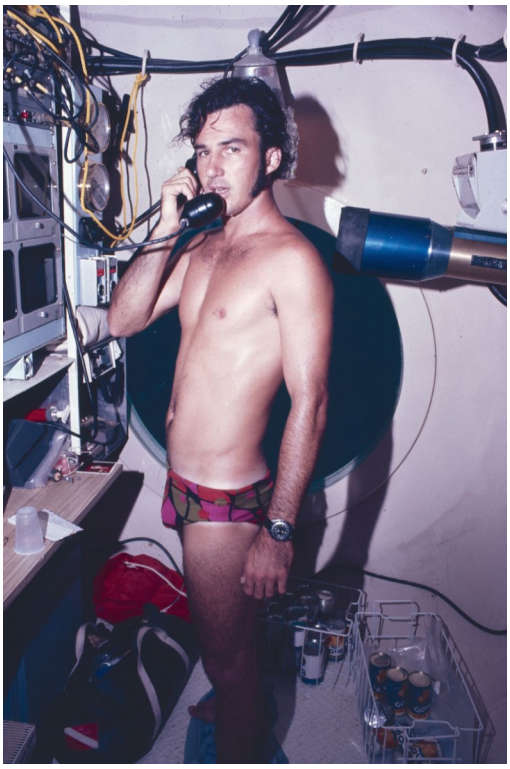

Figure 10. Habitat's mission engineer Mike Dugan talking with PRINUL's base.

Christmas Eve under the sea

On the second morning, we suddenly realized that the day was Christmas Eve and that we never again will experience such a special day in our lives. We needed to celebrate it with something appropriate to our underwater realm. So we suggested that Mike spears a giant Spiny Lobster for Holy Night's feast for us well outside the research area. Mike was delighted to do it because he was an avid spearfisher like myself.

When we arrived back from the day's diving and were in the living compartment, Mike fetched his catch for our appraisal. The lobster was so large that he had to carry it with both hands. We were pleased and told him that it looked just right for our festive meal for Christmas Eve under the tropical

sea. Art offered to prepare a gourmet meal using the lobster and suitable accompaniments from the freezer. That lobster dinner was one of the tastiest and by far the most memorable Christmas supper in my life.

Figure 11. Mike is watching that Art is cooking his catch appropriately.

We had just eaten Christmas Eve's dinner when we heard noises from the subport. We rushed through the hatch to see what was going on there. There we had a delightful surprise: Santa Claus and his helper had emerged into the dive opening. They brought us a Christmas tree and a welcomed present, a case of Mayaguez Breweries' Corona Beer. Santa Clause was Angel Nazario, and another safety diver was his helper. Although drinking any alcohol during the missions was prohibited, at Christmas, it was Ok.

Angel also brought us daily mail into La Chalupa. He was my good friend and former research assistant in the marine ecology section of the PRNC. I also had got lessons from him in free-diving and SCUBA diving during our work. Angel had attended the Vietnam war, but he told me very little from his experiences in that dangerous war. I only learned that he was flying in helicopters over the hostile territories where Viet Cong fired them below. I could see the Military training and war experiences had made him more mature than other men of his age. When he worked with me, he acted in the job very responsible and trustworthy.

Figure 12. Santa Clause and his helper had traveled from the North Pole to La Chalupa.

Figure 13. Christmas portrait: Art and Seppo at the back, John Mike in the front.

Fish observations

During the dives, I followed the life of fish from a close distance. Meeting them frequently at a specific place allowed me to recognize the same individuals and detect unique aspects of their behavior. For a while, a school of Blue Runner stayed around La Chalupa. When the school swam under the habitat, its members turned upside down. After they emerged from the other side, they turned again to a normal swimming position. They considered the bright white sand being upside?

Figure 14. Frank and John are watching our live TV (photo Art Dahl).

In the evening we placed a bright light outside the porthole. Soon it was surrounded by clouds of plankton, which in turn attracted schools of feeding small fish. They lured predatory fish to circle outside the lit area. Occasionally one of them would shoot through the school and capture one fish.

I managed to see a few new, mainly pelagic species such as various mackerels and jacks, that I had not encountered before. A special price for me was the roosterfish with its seven long rays in its dorsal fin. It was surprising that we did not see any sharks. When I had recently been in Bikini Atoll, there were numerous sharks even in the lagoon.

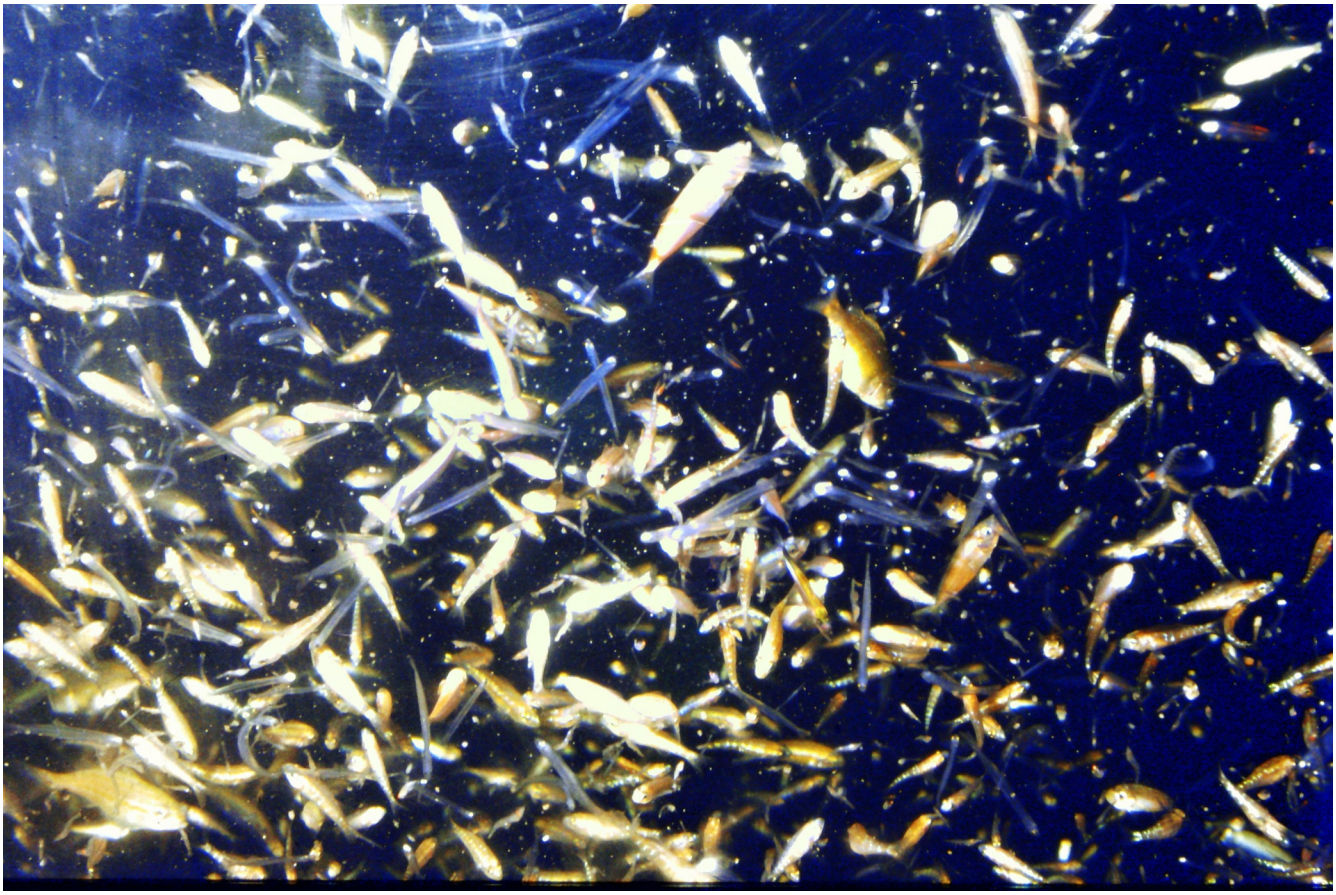

Figure 15. A mixed school of small fish around the underwater light.

When the evening darkened, we placed a watertight light outside the porthole of the living compartment. Watching through the porthole was our underwater TV. It allowed me to see several fish species that I had not encountered before during hundreds of diving hours. I knew them only by the pictures of fish books.

As soon as the light illuminated its surroundings, we could follow the piscatorial food chain's whole succession. First, clouds of zooplankton started swarming around the lit area. Within the cloud were various types of Copepods, juvenile stages of Crustacea, including shrimp and crabs. This ample food supply attracted herds of small fish to feast on it.

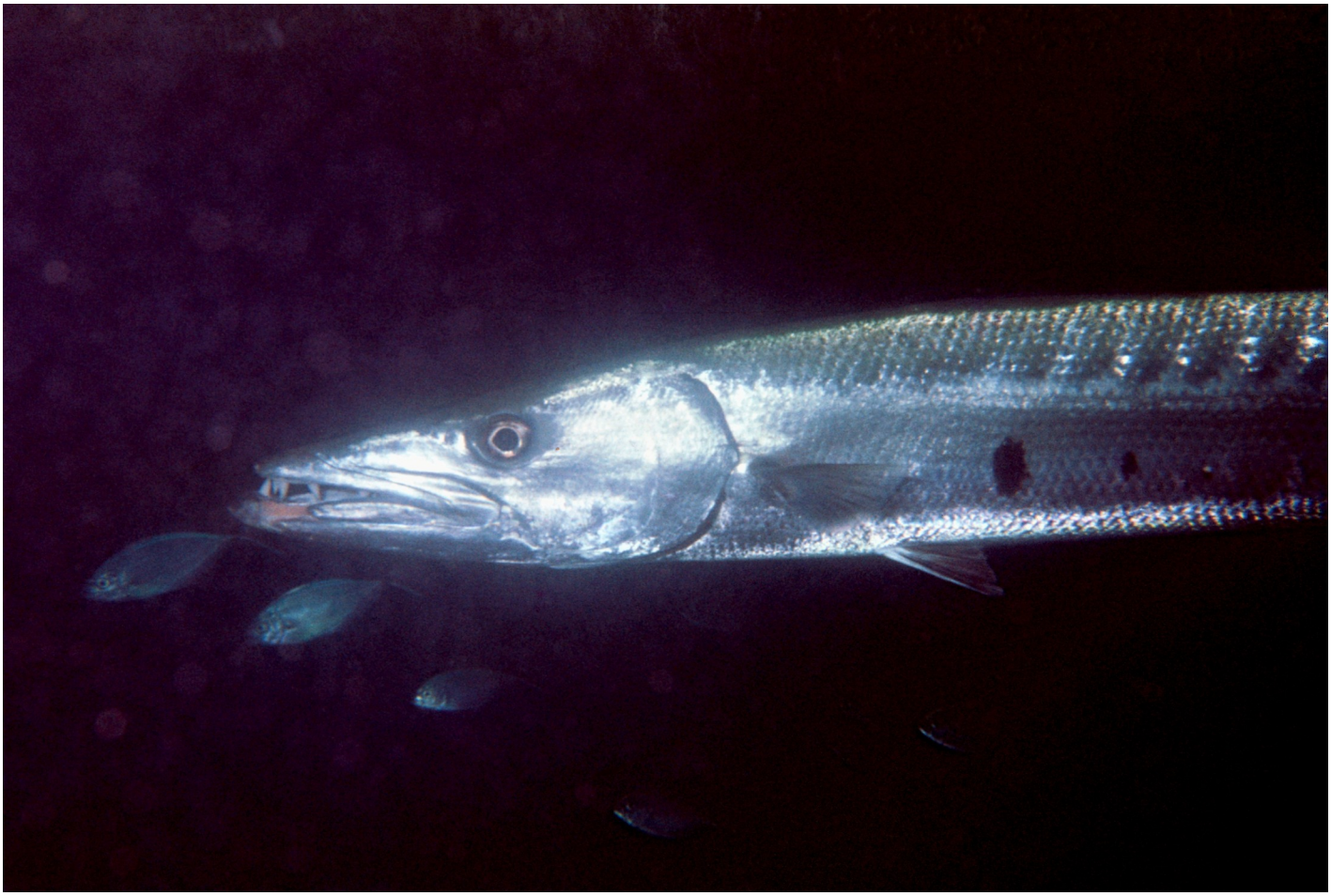

Figure 16. A large Great Barracuda lay in ambush under La Chalupa for a couple of days.

Occasionally, a vast beasts shot through the dense school of bate fish. The fish were different species of predators from the reef, such as Snappers and Jacks. Occasionally, pelagic fish, such as Mackerel, Blue Runner, Tuna, and Sharks, shot through the boiling mess of baitfish. One night, I finally was lucky to be watching the porthole to spot a Roosterfish that I had for years wanted to see.

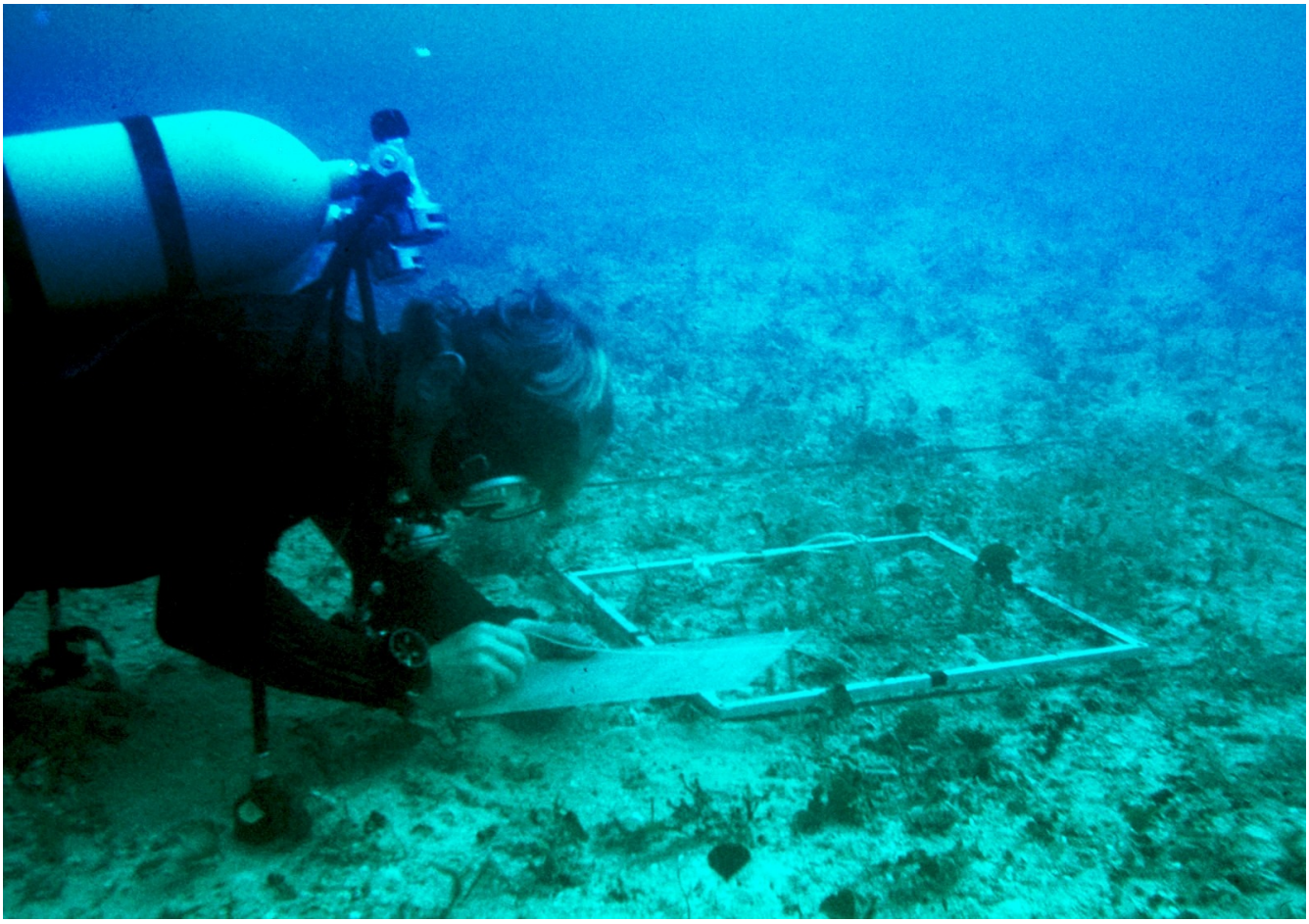

Figure 17. I am identifying and enumerating benthic organisms on the sand flat.

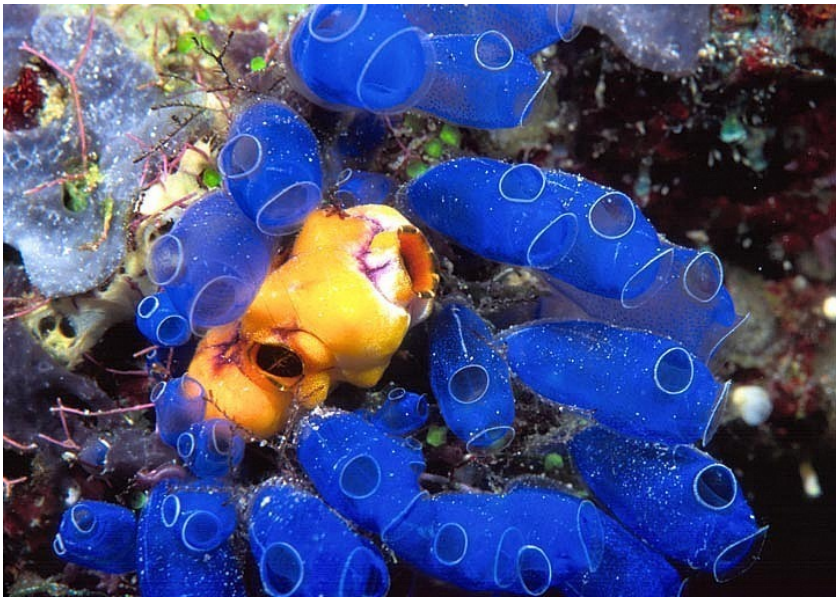

Figure 18. Blue-bell Sea-squirt (Clavulina sp.) form sack-like colonies.

Figure 19. Strawberry-tunicate Eudistoma sp.

Enumerating of benthic organisms

Art studied algae species on the reef and the sand flats. Frank studied coral populations on the reef. John collected seawater samples on the reef and sand flat for analyses in his lab at PRNC. I had chosen for my research to enumerate and identify benthic organisms on the reef and the sand flats near La Chalupa. In my survey, my main interest was in Tunicates. I found 34 species of sessile Ascidia -Sea Squirts at the reef and the sand flats around La Chalupa. Their spinal cord makes them a distant relative of higher organisms. Even though they belong to a subphylum of sessile invertebrates, only a handful of studies on these organisms exist.

Although Sea Squirts have the spinal cord like the vertebrates, they have no backbone. Some live as solitary individuals, while most of the form brightly colored sacklike colonies. The sack is of cellulose type polysaccharide. Larger species are edible and eaten, especially in Asia.

Their "tadpole larva" swims for some time as a free planktonic organism. Eventually, the larva attaches to a solid substrate and loses its tail and ability to move. Then its nervous system partly disintegrates.

Pete Schroeder, whose doctoral theses I supervised, had a brother who was sailing on the oceans looking for marine organisms that had potential substances for the pharmaceutical industry. One group that he was especially interested in was Tunicates.

During the dives, I also took many color slides of the reef and its organisms, especially fish. I made longer dives than other members of our team. My diving time was 64 hours.

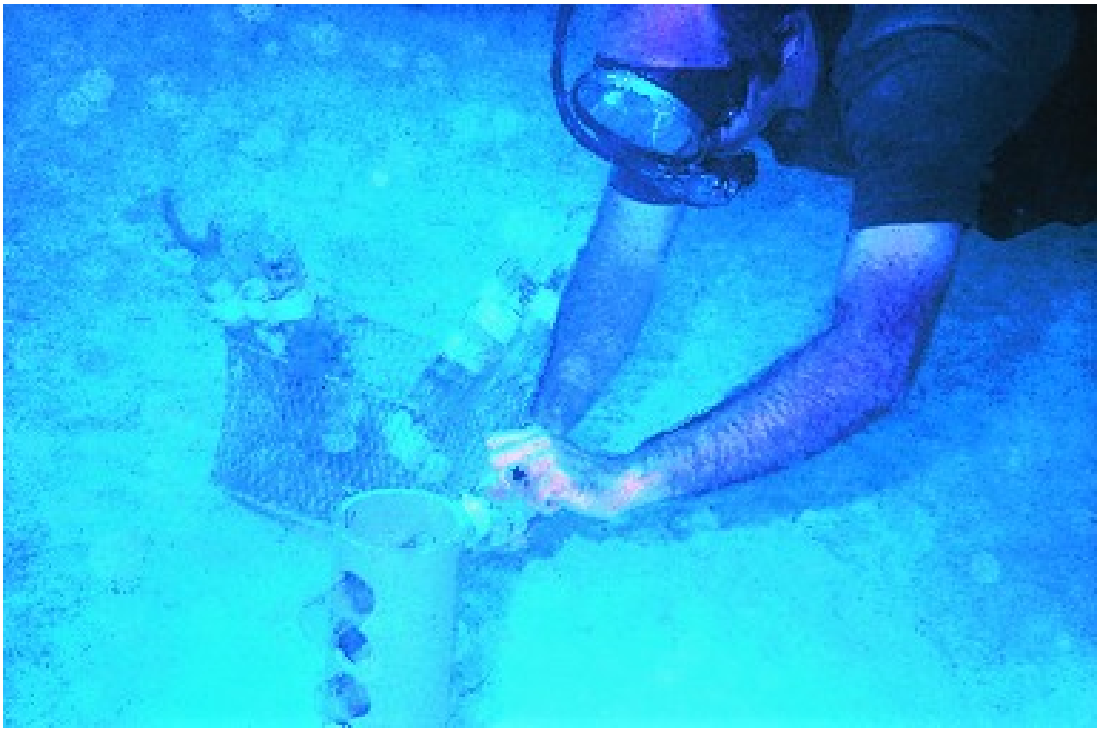

Figure 20. John collecting water samples on the sand flat near the reef.

Figure 21. Seppo taking photographs on the reef front (photo Art Dahl).

21 A hairy situation in La Chalupa

A few days after Christmas, our whole crew started feeling drowsy that, so some of us began to take naps. It felt like the air had been heavier than usual. After we got concerned with the unusual tiredness, Mike started going over all equipment one by one. Eventually, he discovered that the problem was caused by habitat's air.

To minimize the exposure to the toxicity of oxygen, the flow of fresh air low until the partial pressure oxygen dropped to 7%, which equaled 21% in the global atmosphere. Our breathing produced carbon dioxide, while at the same time, we consumed oxygen. Fresh air brought into habitat new oxygen.

But to remove carbon dioxide from our atmosphere, air circulated through a lithium hydroxide filter that captured it from he air. Mike's maintenance included changing the lithium hydroxide filter daily. But that day, Mike had forgotten to make the change.

When Mike measured the carbon dioxide concentration in our air, it was over 2%. That explained why we had felt so tired and sleepy. Had everybody taken a nap, it could have lasted forever because the lethal level for human beings is 4%. After Mike changed the filter, our condition improved quickly, breathing turned lighter, and we felt alleviated.

In the 1970ties, global dioxide level in the atmosphere was 325 ppm (parts per million). Compared to that we were exposed to over 60 times higher level. Since then to the year 2020, the global carbon dioxide level has grown to 411 ppm.

Figure 22. A safety diver checked the vital instrument systems. every day.

Unfortunately, toward the end of the mission, we ran out of delicious frozen food that came from the Miami restaurant. Then Angel brought us a case of canned Minestrone. After eating it for three days, we were fed up with Minestrone soup and didn't want to see or smell it anymore. Then we called PRINUL and insisted on getting anything else but Minestrone.

That day we were eagerly waiting for the safety divers' visit. When they appeared at the diving entrance, we were anxious to tosee some tasty food after two days of canned soup. As Angel's head popped up from the water, our eyes were gaping at what he was lifting from the water, and guess what? There was – *more Minestrone.*

Decompression

During the mission, we had been living for two weeks in the 3-bar atmosphere. Oxygen's partial pressure had been that 7% corresponded to the atmospheric level of 21%. However, nitrogen's partial pressure had been three times higher. It meant that our body fluids' nitrogen level was three times higher than the global atmosphere. Before returning to the surface, we had to removed the excess nitrogen from our tissues by gradual decompression. It prevents nitrogen bubbles from forming and blocking the blood vessels and causing decompression sickness. Everybody came to the living compartment and we closed its pressure door and the decompression started already while La Chalupa was on the bottom.

PRINUL's diving crew were busy around the habitat and on the Support Vessel. The were pumping air to replacing the seawater in the trim tank and ballast tanks. Gradually the barge started ascending towards the surface. Our decompression continued during the towing to the harbor and at the dock until the next morning. For every hour, the pressure lowered at a rate equal to three feet of water.

Each hour we were breathing the ambient air for 40 minutes, after which we inhaled pure oxygen for 20 minutes through a mask. Two weeks at a saturation depth of 18 meters required 23 hours of decompression. All that time, we had no communication with the outside world.

Figure 23. Art using the oxygen mask during the decompression.

Accident in the harbor

After La Chalupa had arrived in the harbor basin's middle, we watched through the porthole it's tying to the pillars on the docks. While the barge was still away from the pier, we saw a thick steel cable and a person flying past the window. He fell into the water outside our view, so we did not know whether he was hurt. After that, panicky people were running on the docks in all directions. Then we realized that we had seen a severe accident happening before our own eyes. Without any communication link with the outer world, the accident left us with many unanswered questions.

Not until we got out of the decompression the next morning we learned what had happened. The diving director, Frank Milhoan, had been fastening moorings to the corner post on the deck of La Chalupa when a sudden gust of wind forced the barge to turn and a moving cable wrapped around his wrist. It catapulted him to the harbor's basin and broke his wrist bones.

In the Mayaguez Medical Center, a surgeon could not repair the wrist due to too many crushed bones. He cut Frank's arm at the wrist. Unfortunately, gaseous gangrene developed in the arm after two days. The surgeon removed all infected muscle tissue and amputated the upper arm near the shoulder. The procedure left Frank only a short stub of the upper arm. Because the hospital had made severe errors in the treatment, Frank started a maltreatment lawsuit against the medical center.

After the amputated arm healed, Frank continued working at PRINUL. He was by no means handicapped but managed well in all duties with one arm. He received an arm prosthesis after the PRINUL program had ended.

I had the good luck to have him as the habitat service engineer during my second time in La Chalupa, later in 1973. It was the eighth of PRINUL missions.

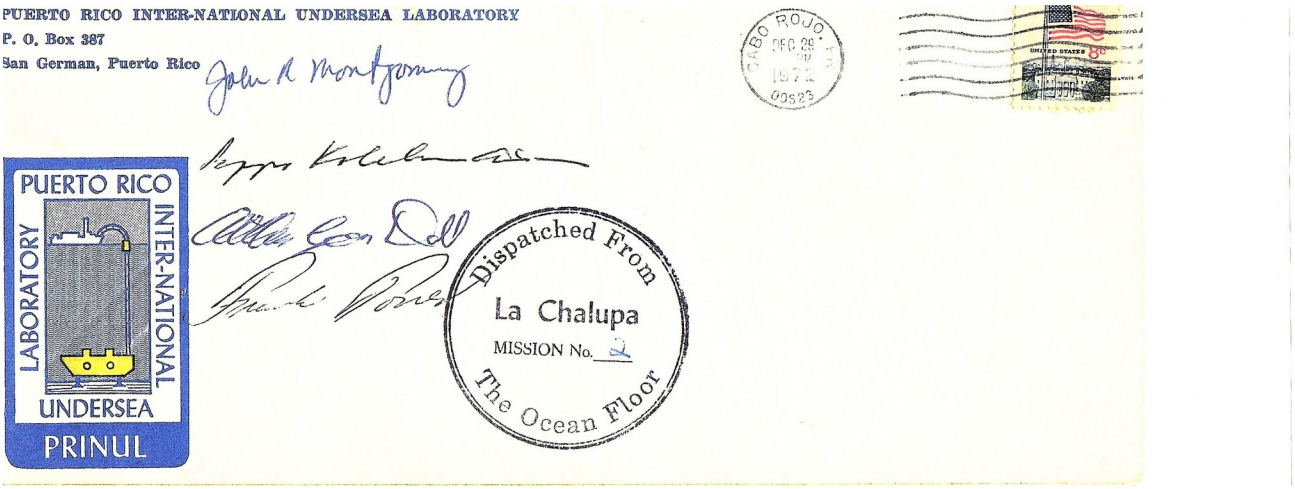

Figure 24. A signed envelope of Mission #2.

Figure 25. Decal of Manned Undersea Science and Technology.