# Using the SGPT Chamber for Field sampling and long-term captivity of deep demersal fishes from tropical waters

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## Abstract

Because of the strong influence of the warm Kuroshio Current from the south, the marine fauna off Okinawa Island is characterized by beautiful tropical coral reefs and many colorful tropical fishes. For over 3 decades, since the opening of the former Okinawa Expo Aquarium, now called the Churaumi Aquarium, we have been collecting deep-sea fishes from the depths of 100-980m off Okinawa Island (25 27°N), and trying to keep them alive for research and exhibit purposes. In general, it has been very difficult to achieve long term success in keeping deep-sea demersal fishes, owing to the differences in pressure between the deeper and surface waters, and in tropical waters, differences in temperature as well. A difference in pressure is a relatively simple problem to solve by using pressurized collecting and keeping tanks, but they are prohibitively expensive. In this publication we introduce our successful and economically feasible experiment in treating decompression disease by using our SGPT (Simple Gravity Pressure Treatment) Chamber, which is pressurized by the forces of gravity produced by a tall narrow water column.

## Introduction

Most deep-sea fishes inhabiting depths below 200 m have generally been considered unsuitable for exhibit in aquariums worldwide, owing to the difficulties in providing them a habitat with adequate pressure for survival. However, owing to their unique habitats and curious morphologies, many aquarists desire to keep them alive for study and display. As Uiblein et al. (2010) noted, *ex-situ* observations can contribute profoundly to behavioral research on deep-sea fishes. Recent technological advances in deep-sea observation equipment, such as ROVs (Remotely Operated Vehicles) and high definition movie cameras (Kubodera, 2010), for *in-situ* observations, are helping to introduce the mysteries of the deep-sea world to scientists and TV viewers alike.

However, such *in-situ* observations on the deep-sea inhabitants are quite limited, because of the constraints on viewing time and points of observation.

In order to fully study reproduction, feeding behavior and functional morphology of deep-sea fishes, captive observations are of utmost importance. In recent years, several attempts have been made to keep collected deep-sea fishes alive. Koyama et al. (2002, 2005), and Koyama (2007) developed a hyperbaric aquarium system with which they succeeded in capturing and keeping deep-sea zoarcid fishes from below 1000m. Drazan (2005) designed a hyperbaric trap-respirometer system to keep pressure at capture depth and performed *ex-situ* physiological experiment on deep-sea grenadiers. These recent experiments were conducted using very small, quite complex, and extremely expensive high pressure tanks, and also required large research vessels and many technicians.

At the Okinawa Churaumi Aquarium, we have been trying various methods to keep deep-sea fishes in captivity, and have succeeded in displaying live deep-sea fishes such as the ruby snapper (*Etelis corscans*), snake mackerel (*Thyrsitoides marleyi*), threetooth puffer (*Triodon macropterus*) and several deep-sea squaloids. Our samples of deep-sea fishes are taken mainly by using hook and reel, traps, long-lines and occasionally an ROV, but few species survived. In order to improve our results, we reconsidered our collecting and keeping methods.

According to our observations made on dead samples, the "bends" or "decompression sickness" is the most significant factor prohibiting long-term keeping of deep-sea species of fish. Most of the fishes we collect from the deep suffer decompression sickness, exhibiting expansion of the swimbladder, protrusion of the stomach from the mouth and eventual tissue necrosis by thrombosis. Visible symptoms, like an expanded swimbladder, are possible to treat artificially and simply using surgical instruments. But other symptoms such as bleeding at the fin tips and edges, invasion and infection of the necrotic tissue by bacteria etc., invariably result in death. For our research, we turned to studies of decompression sickness and successful recompression attempts in humans, and decided to apply some of the same principles and solutions to our design for a recompression facility for deep sea animals. Here we introduce our concept for a pressurized tank, the Simple Gravity Pressure Treatment (SGPT) Chamber, and report an example of successful treatment of decompression sickness of a deep-water catshark using the Chamber.

## Materials and Methods

### *Chamber design*

The design goals of our SGPT Chamber included: (1) a relatively low pressure and relatively large volume tank, (2) an extremely silent and stable tank environment, (3) a simple and easy-to-operate design (4) safety features for power failures and operating mistakes. Our initial idea, an appropriately deep, cold, high-pressure tank would have many disadvantages: besides the high costs of construction and maintenance, and the difficulties of quieting a noisy compressor, it would also be difficult for a diver to routinely conduct research in those conditions. A second idea, a small closed tank with high narrow water column (Fig. 1B), can produce the same pressure in the deep square tank (Fig. 1A), but would only be appropriate for brief periods of research, not long-term. Finally, we devised a special SGPT Chamber (Fig. 1C) which satisfied our design goals and which we report on here. It consists of a 300 L (Fig. 1D) holding tank on the ground floor of Okinawa Churaumi Aquarium, with two polyvinyl chloride columns reaching up to smaller tanks on the fourth floor (18 m above the ground), and two smaller satellite tanks each on the third (10m) and the second (5.5m) floors (Fig. 1E). It is a circulating system, each tank with inlet filters to help keep water quality clear, and with shut-off valves on each floor to create variable pressures in the holding tank. With this SGPT Chamber, we have achieved adequate pressures for successful recompression of fishes caught in the deep-sea.

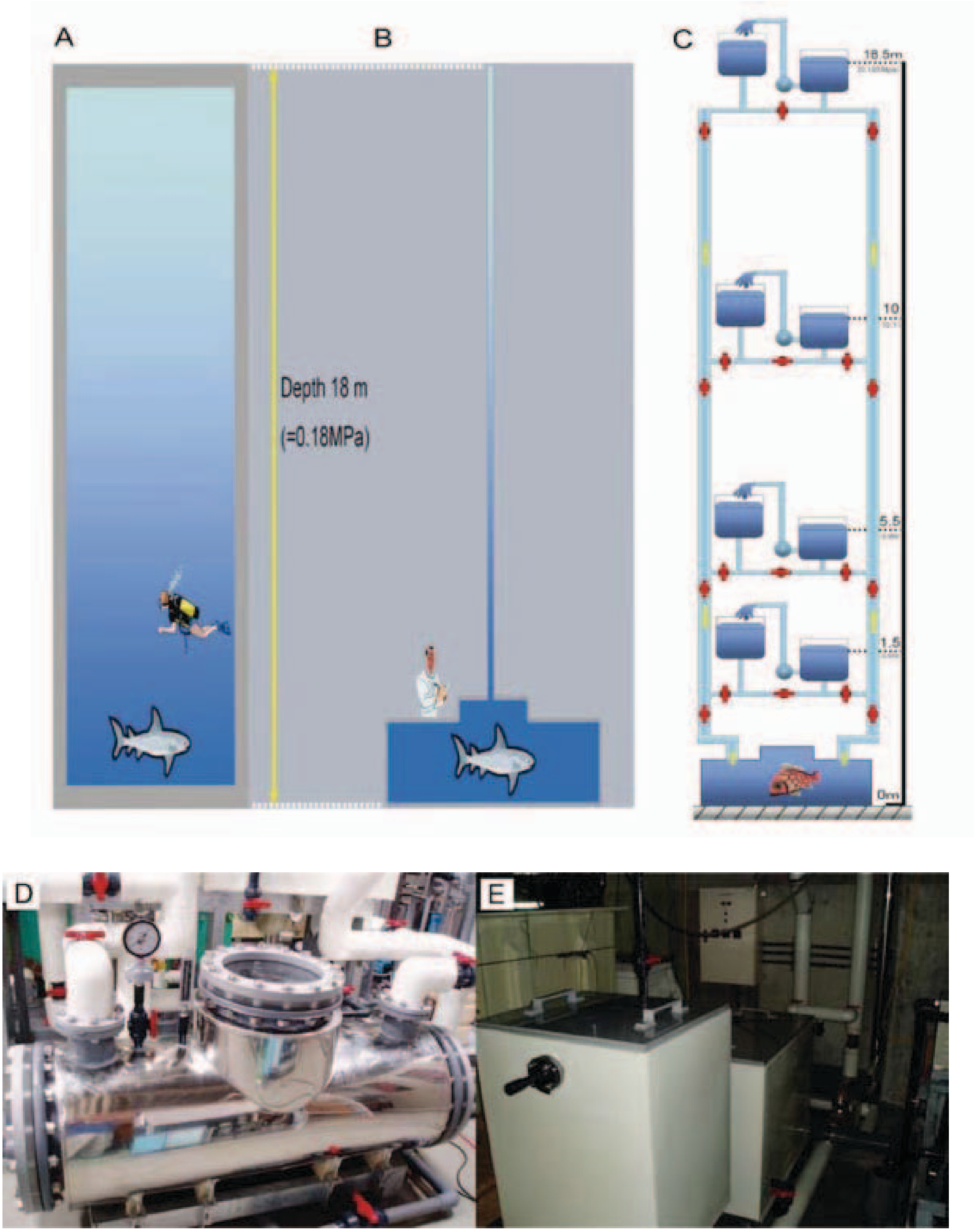


**Fig. 1**. Diagrams of design ideas for deep-sea chambers all with 0.185 Mpa water pressure. (A) an 18.5m deep square water tank, simple but expensive and difficult to access. (B) a closed tank with a narrow water column but not suitable for long-term research. (C) successful SGPT Chamber with system of D and E tanks. (D) 300L holding tank on the ground floor. (E) satellite tanks on the 2nd floor (left: 100L elevated tank; right: 200L return tank).

### *Collecting methods*

The most useful methods for collecting live deep-sea fish for exhibition are by rod & reel and baited traps (Fig. 2A), both methods commonly used by Okinawa's local deep-sea commercial fisheries. We mainly corroborate with Mr. Yukinobu Taira, a local fisherman ("uminchu") in Motobu-cho, Okinawa, chartering his 12m boat, the Kofuku-maru (Fig. 2B), to collect deep-sea fish around Okinawa. Our main targets are deep-sea ruby snapper, sharks and snake mackerel. Caught fish are immediately moved into a small holding tank filled with cold water on board the boat, and then transported to the Aquarium for recompression treatment in the SGPT Chamber.


**Fig. 2**. Sampling equipment and fishing boat. (A1-2) baited trap, (B) rod and reel fishing, (C) fishing boat "Kofuku-maru".

### *Research materials*

An SGPT Chamber experiment was conducted using three individuals of a deep-water catshark species known as Parmaturus pilosus, collected from 650 deep in the East China Sea off Okinawa Is. Surface water temperature at collection (Oct. 22. 2006) was 26.8°C centigrade, and bottom temperature was estimated to be 9°C. All the sharks were trap-collected and transferred by boat and truck to the Aquarium in a tank filled with 10°C water. Duration of transport to the Aquarium was 3 hours. Conditions of the sharks before the SGPT Chamber experiment are shown as follows. Of the two to be kept in the

SGPT (Fig. 3), individual No. 1 (female, TL 53cm) showed normal balance and swimming behavior. Individual No. 2 (female, TL53cm), swam out of balance in a tipped position, likely because of a slightly swollen liver, but nevertheless was suitable for experimentation. NO 3 (female, TL56cm), the control animal, was kept without SGPT chamber treatment for the duration of the experiment in the 230 ton Aquarium exhibit tank (3 m deep, 14°C).

**Fig. 3.** Two samples of *Parmaturus pilosus* under SGPT Chamber experiment (right: individual No. 1; left: individual No. 2).

## Results

Maximum pressure (18.5m, 0.185Mpa) can be reached in the SGPT Chamber within about 5 minutes, but a more gradual drop in pressure helps the fish equilibrate without problems. A sudden drop seems to surprise the fish, causing them to ventilate rapidly.

After reaching 18.5 m / 0.185Mpa the pressure was held steady for ...and then slowly returned to normal surface pressure over a 26-day period.

### *Individual No. 1*

When pressure in the chamber reached the maximum (0.185Mpa), individual No. 1 established a constant position 3 cm above the tank floor, swimming slowly round and round, and maintained that position during the following 26 days of recompression. After recompression the individual was moved to a 7.5 t (cu. m) FRP tank (2m wide, 2.5m long, 1.5m deep) where it swam normally for 49 days, and then began to eat on its own. Two years after being captured, it remains completely free of fin necrosis or other symptoms of decompression sickness, and is still healthy.

### *Individual No. 2*

Individual No. 2 never regained its balance during the same recompression treatment as described for No. 1. Although it remained free of fin necrosis after being moved to the FRP tank, it never was able to feed. Nevertheless, it lived for 238 days after treatment. Likely cause of death was starvation. However, examination of its liver revealed the oil droplets characteristic of decompression sickness in animals collected from the deep sea and kept for a short time in an aquarium tank.

### *Individual No. 3*

Although still seemingly normal on the fourth day after capture, on day 5 individual No. 3 began to show the abnormal swimming behavior typically associated with decompression sickness. On day 9 it swam weakly at the surface, its back projecting slightly above the water. By day 13 its caudal fin, anal fin, two dorsal fins and nearby skin areas were becoming necrotic and it had difficulty swimming. It finally died on day 28. Dissection after death revealed many oil droplets in the liver (Fig. 4), many more than observed in the recompressed No. 2 at its death.

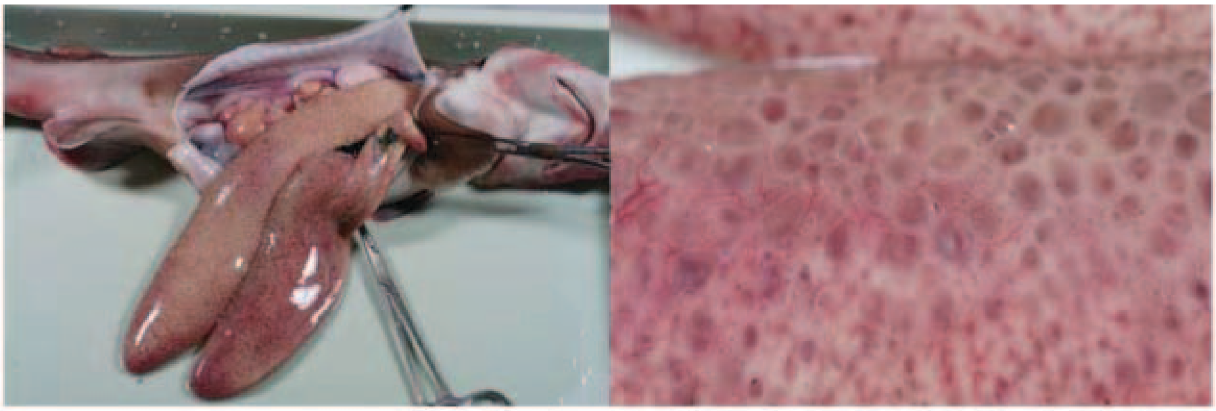

**Fig. 4.** Necrotic liver of Individual No. 3 dissected after its death (left). Many oil droplets can be observed on the surface of liver (right).

## Discussion

Results indicate that recompression was completely successful for individual no. 1. Individual No. 2, although exhibiting out-of-balance swimming behavior, nevertheless lived for 238 days, dying of starvation not decompression sickness. Its decompression symptoms (oil droplets in the liver) at death were much less severe than in untreated individual No. 3. No. 3 showed the fin necrosis and liver damage typical to captive animals suffering decompression sickness heretofore kept here and in aquariums around the world. A world-first for successful recompression, our system is further attractive because it is both inexpensive and simple. Although it creates a relatively low (18.5m) pressure, it is very effective. Ultimate success of course is dependent on the species, individual differences, capture conditions, etc.

Although success is not always 100 percent, even animals collected from depths of 650m have been successfully recompressed with our system. As we continually revise our recompression regime and improve structural details of our system, we expect better and better results.

## Afterword

This SGPT Chamber is effective not only in alleviating normal symptoms of decompression sickness, but has also shown great effectiveness in resolving other problems related to keeping both shallow-water and deep-sea animals, such as bulgy eyes, wounds and abnormal swim bladder metabolism.

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