

RESULTS OF THE TEKTITE PROGRAM: ECOLOGY OF CORAL-REEF FISHES

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Tektite was the first nationally sponsored scientists-in-the-sea program. It was a cooperative government-industry-university effort that took place in Lameshur Bay, St. John, Virgin Islands in 1969-70. One goal of the program was to show that saturation diving from an underwater laboratory could be done efficiently, safely, and at a relatively small cost, using a breathing mixture of nitrogen and oxygen. During Tektite II, General Electric rebreathers were used which greatly extended the time that divers could spend in the water away from the Tektite habitat. Nine studies dealing with various aspects of the ecology of coral-reef fishes were carried out during Tektite I and II: Influence of herbivores on marine plants, bio-acoustic studies, observations on cleaner shrimps, isopods associated with reef fishes, behavior of reef fishes in relation to fish pots, bioturbation by the sand tilefish, escape response in a damselfish, nocturnal-diurnal changeover in activity patterns, and space resource-sharing. An example of the efficiency possible with Tektite and rebreathers is shown by the nocturnal-diurnal changeover study. Information gathered in 100 hrs is comparable to that accumulated for a study in the Gulf of California based on 1200 hrs underwater over a two-year period. The 86 hrs in the water logged by Sylvia Earle in her herbivore-algae study during two weeks would have taken a minimum of two months to accomplish assuming perfect weather conditions and no equipment failures.

INTRODUCTION

While considering new ways to learn about the major portion of Planet Ocean, which humans have mis-named Earth, it is also valuable to recall past efforts to insure that what we learned from those efforts is not forgotten in the rush to make new plans. It is with this purpose that I want to revisit the Tektite program (Collette and Earle, 1972). Tektite II was the first real underwater laboratory (Miller and Koblick, 1984). Many important programs preceded Tektite but in those programs engineering, biomedical, and safety concerns dominated and the marine science that was carried out was almost incidental to proving that it could be done. Scientists were selected as Tektite aquanauts primarily on the basis of research proposals submitted, and secondarily on the basis of health and diving skills. It is far easier to teach scientists to dive than to teach divers to be scientists.

Tektite I and Tektite II were nationally sponsored scientists-in-the-sea programs carried out in 1969 and 1970 as cooperative government-industry-academic programs. Both were based in Lameshur Bay, St. John, in the U.S. Virgin Islands. The Office of Naval Research coordinated Tektite I, the Department of the Interior Tektite II. In Tektite I, four men lived in the Tektite Habitat for 60 days, whereas Tektite II comprised ten missions lasting 10-20 days with four scientists and an engineer on each mission.

The Tektite Habitat was designed and constructed by the General Electric Company. From the outside, the Habitat looked like a pair of silos: Two white metal cylinders 4 m in diameter, 6 m high, joined by a flexible tunnel and seated on a rectangular base in 15 m of water (Fig. 1). Multiple cords extended from the Habitat to the shore for air, water, and electric power. A flexible pipe led seaward for 300 m to a site in 22 m where sewage was pumped from the Habitat.

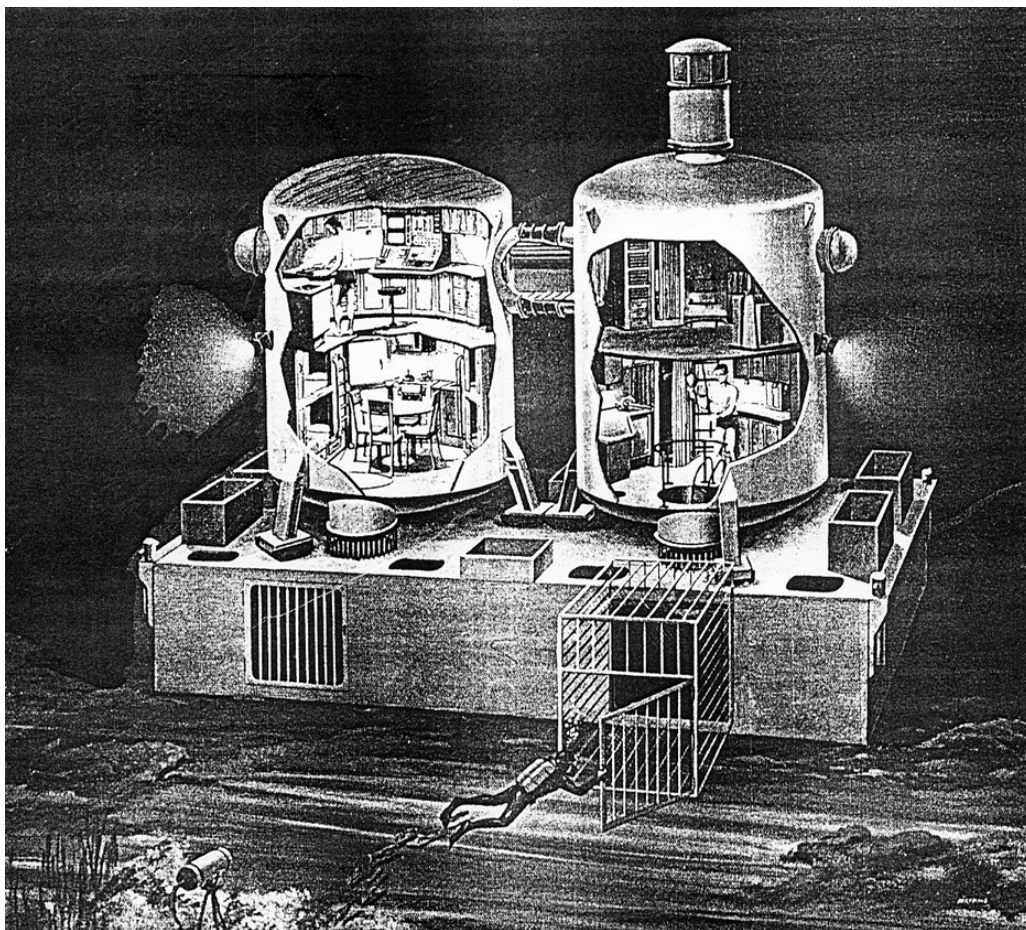


Figure 1. Cutaway view of the Tektite Habitat showing arrangements of the four rooms.

Inside, the Habitat had the combined features of a laboratory and an apartment. There were four rooms, two in each cylinder. The main entrance was in the floor of the "wet room", a laboratory and storeroom for scientific and diving equipment. A submerged ladder led down into the sea through an open well. Pressure was maintained at 2.5 atm, sufficient to keep water from rising through the entry well. The wet rooms served primarily for pre- and post-diving operations but also housed a clothes dryer and a hot freshwater shower.

Above the wet room was the engine room containing essential life-support systems, a freezer for food storage, and a small but private bathroom with sink and toilet.

The third room, the control room or bridge, was reached by crossing through the tunnel connecting the two cylinders. Communications and monitoring systems were located there. This room also served as a dry laboratory, library, and was the primary domain of the Habitat engineer who even slept there on a

folding cot.

The room below the bridge was the crew quarters. Four built-in bunks with draw curtains and personal storage drawers filled two sides of the room; another section housed a refrigerator, stove, sink, and storage cupboards. A table in the center of the room served as dining surface and desk. An emergency escape hatch was located in the floor of the room.

The atmosphere inside the Habitat was pleasant. Carpeted floors, varied colors, good lighting, controlled temperature and humidity, and taped music and television, contributed to the comfort and livability of the Habitat. Large hemispherical ports enhanced each room, aesthetically as well as scientifically. Observations were possible through the ports so much reef activity could be observed.

Lameshur Bay was chosen as the site for the Tektite program because of a number of favorable characteristics. The site is relatively undisturbed because it is within the Virgin Islands National Park. There is a great variety of plant and animal life with a varied terrain including coral reefs, sea grass beds, and an extensive sandy plain. Excellent studies conducted in the area prior to 1969 by John E. Randall provided a firm base of scientific knowledge that complemented and facilitated research undertaken during the Tektite program.

During Tektite II, we utilized General Electric Mark 10 Mod III rebreather units. This closed system produced no noisy bubbles and eliminated the up and down movements caused by inhaling and exhaling. Use of rebreathers also eliminated the low air-supply problem because the units were capable of 12 hours continuous operation, although in practice during Tektite, rebreather dives were limited to about four hours each as a safety precaution.

Despite the time required for communications, safety measures, personal maintenance, sleep, meals, and other non-research activities, the time that was available for productive research in the water, day after day, exceeded that previously experienced by any of the aquanauts. Prolonged time in the water is the most obvious advantage of saturation diving from a habitat, but it is not only the number of hours per day that is significant for some research. It can be important to make observations throughout a 24-hour cycle to gather information on diurnal and nocturnal behavior.

ECOLOGY OF CORAL REEF FISHES

Nine studies conducted during Tektite I and II dealt with some aspect of coral-reef fish ecology. I summarize these studies from the papers and abstracts in Collette and Earle (1972) with an emphasis on factors significant in evaluating marine research done from a habitat with rebreathers.

The influence of herbivores on the marine plants of Great Lameshur Bay. S.A. Earle.

Thirty-five species of plant-eating fishes in 14 families were observed in Lameshur Bay. A total of 154 species of plants were found, including 26 new records for the Virgin Islands. Cage-exclusion experiments showed appreciable growth inside cages in areas where plant-eating fishes were abundant. Most adult plant-eating fishes were active in the daytime and rested at night. Herbivorous fishes strongly influence the abundance, diversity, and distribution of benthic marine plants in tropical seas. The 86 hrs in the water logged by Sylvia Earle in her two week-study would have taken a minimum of two months to accomplish assuming perfect weather conditions and no equipment failures.

Bio-acoustic studies on reef organisms. T.J. Bright.

Diver-carried portable recording units and stations monitored with Habitat-based equipment were used to record acoustical behavior in several species of reef fishes. Sounds were recorded from species of

squirrelfishes (Holocentridae), parrotfishes (Scaridae), goatfishes (Mullidae), and groupers (Serranidae). Use of rebreathers greatly facilitated recording fish sounds without the noise produced by the bubbles from open-circuit scuba systems.

Observations on cleaner shrimps of the genus *Periclimenes*. C. Mahnken.

Two abundant cleaning shrimps, *Periclimenes pedersoni* and *P. yucatanicus*, were almost invariably associated with the anemone *Bartholomea annulata*. The highest concentration of cleaning shrimps were in the sand strip adjacent to the coral reefs which seemed to offer the shrimps the best opportunity for meeting fish "clients."

Cymothoid isopods associated with reef fishes. F.G. Hochberg, Jr. and R.J. Ellis.

Movements of over 160 longjaw squirrelfish (*Holocentrus ascensionis*) were followed using locations of isopods of the genus *Anilocra* as tags marking different individual squirrelfish.

The behavior of reef fishes in relation to fish pots. W. High and A.J. Beardsley.

Three different fish-pot designs were compared. The Virgin Islands pots caught more fishes than the experimental collapsible pots, but the fish were smaller in size.

The sand tilefish, *Malacanthus plumieri*, and the distribution of coarse debris near West Indian coral reefs. H.E. Clifton and R.E. Hunter.

Sand tilefish construct burrows in the sand that are roofed with mounds of shell and coral debris. Within eight days, a single fish restored nearly 500 marked fragments to a partly disrupted burrow. Sand tilefish will move at least 9 m from the burrow to collect appropriately shaped fragments.

Escape response in a pomacentrid reef fish, *Chromis cyaneus*. A.E. Hartline, P.H. Hartline, A.M. Szmant, and A.O. Flechsig.

Flat plastic models were pulled horizontally on a pulley system near a coral head that was home for a school of plankton-feeding *Chromis cyaneus*. The *Chromis* exhibit a stereotyped escape response consisting of flight toward the shelter of crevices in the coral reef. Speed of model approach and shape were unimportant but differences in size and color or shade caused differences in escape behavior.

Activity patterns of coral-reef fishes with emphasis on nocturnal-diurnal changeover. B.B. Collette and F.H. Talbot.

Fishes were studied at reefs at 15 m and 23 m to document changeover from nocturnal to diurnal behavior and vice versa. Fish activity was recorded at 5 minute intervals; data is of reasonable quality for 35 species. Diurnal species appeared as early as 05:40 and all species were usually active before 06:45. The sparse nocturnal fauna, primarily cardinalfishes and squirrelfishes, became active between 18:12-18:35, after the diurnal fishes had already disappeared. Information gathered in 100 hrs in this study is comparable to that accumulated for a similar study in the Gulf of California based on 1200 hrs underwater over a two-year period. Being able to dive with hookah on a morning when normal rebreather diving was not possible because safety divers could not go out showed that delay and extension of changeover in several species of fishes was correlated with storm-caused turbidity, indicating that these fishes have a primarily exogenous clock.

Space resource sharing in a coral-reef fish community. C.L. Smith and J.C. Tyler.

Population counts and habitat selection were observed day and night for the fishes of an isolated coral-patch reef at 11.5 m for 15 days. The fish fauna of the patch reef included 53 resident species and 22 species that were visitors or transients. Major aspects of space sharing included diurnal versus nocturnal activity, feeding and hunting areas, shelter sites, territoriality, seasonal cycles, and symbiotic relationships. Fishes residing inside specific sponges were checked every hour one night, a procedure

that would have been very difficult to carry out from the surface.

CONCLUSIONS

There no longer seems to be any question about the great value of living and working in the aquatic area that you are studying. There has been more discussion on whether such research is economically justified. Tektite can easily be justified because costs were divided between marine research and other kinds of research: Biomedical, psychological, habitability, etc. (Miller, 1970). It is more difficult to justify the costs based on the value of the marine research alone. One of the purposes of the volume on ecology of coral-reef fishes that Sylvia Earle and I edited (Collette and Earle, 1972) was to present a block of this research so that it could be evaluated.

We made a number of recommendations based on the Tektite program and it might be valuable to consider some of them with regard to new programs such as the next generation of *Aquarius* (Shepard *et al.*, this volume) and the OASIS program (Cooper and Babb, this volume). Although not directly related to saturation diving from a habitat, I am amazed and greatly disappointed at the failure to replace standard open circuit scuba with rebreathers. Rebreathers are more expensive, but if one can accomplish twice the work in a given unit of time and carry out investigations that take more bottom time than is available with scuba, is it really more expensive? I question the validity of all fish behavioral studies done with scuba because of the demonstrated disturbing effects of the noisy bubbles. Jacques Cousteau wrote of the "silent sea," but it is not really silent; we just cannot hear all of the biologically generated sounds because of the noise of scuba bubbles.

The next generation of *Aquarius* (Shepard *et al.*, this volume) plans to have 24-hour work days for aquanauts instead of 12 hours. But we already had 24-hour work days in Tektite. How and why did that get changed? The next generation plans for consumables to be stored in the habitat. We had delicious habitat-cooked meals on our Tektite mission. The next generation plans for excursions not limited by sea state but as we showed in our day-night work, we could work effectively in the water on hookah during a severe storm. Increased numbers of missions, better communications, and reductions in costs are very important goals.

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