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HYPOTHESIS-BASED RESTORATION STUDY FOR MITIGATION OF A S.E. FLORIDA U.S.A. CORAL REEF DAMAGED BY THE GROUNDING OF A NUCLEAR SUBMARINE

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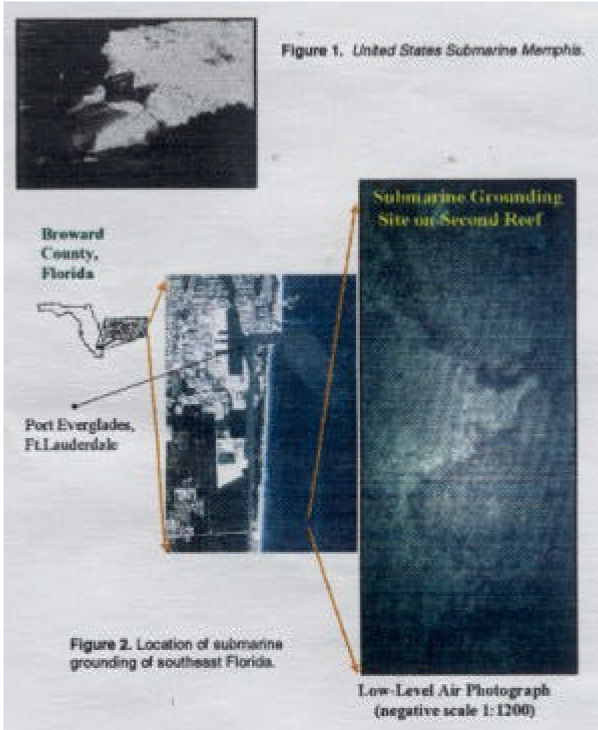
INTRODUCTION:

The *United States Submarine Memphis* (Figure 1) ran aground in approximately 10 meter depth on a coral reef off southeast Florida (Figure 2) February 25, 1983. Extensive physical damage to the reef substrate and injury to the coral community were attributed to the initial grounding and subsequent attempts to tree the submarine from the impacted reef (Figures 3 and 4). The impact of the grounding was assessed, and the area of damage was determined through field and photographic studies.



An impacted area of 2,310 m^2 was assessed with 1,205 m^2 having been totally destroyed (Figures 3 and 4). In 1997, the State of Florida was awarded a settlement of $750,000 by the Federal government for environmental damages caused by the submarine grounding. A plan to perform hypothesis testing of restoration techniques was developed and initiated.

Using artificial reefs as experimental platforms, we are examining three restoration strategies: 1) the potential of enhancing coral recruitment through the use of coral larval attractants, 2) the effect of reef structure on the associated fish assemblages, and 3) the interaction between fish assemblages and coral recruitment and survival.

Figure 3. Trench hole (3 m depth) excavated by the submarine's propeller during attempts to free itself from the reef.

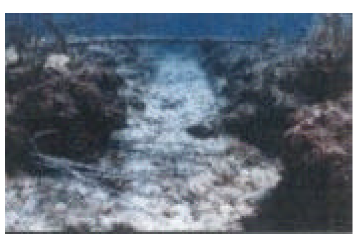


Figure 4. Entry gouge approximately four years after the grounding.

METHODS:

One hundred and sixty small artificial reef modules (Reef Balls™) will be deployed in 11 m of water on a sand flat between reef hacks adjacent to the *U.S.S. Memphis* grounding sit (Figure 5). The Reef Balls will be organized into 40, 4-module reef units (quad) in a square configuration having approximately 4 m sides (Figure 6). The separation of individual Reef Balls (2 m) is judged sufficient to avoid interaction effects between Reef Balls in terms of coral settlement, but close enough for the 4 balls to function as a single reef unit in terms of fish recruitment. Each quad will be located a minimum of 30 m from any hardbottom or other quads.

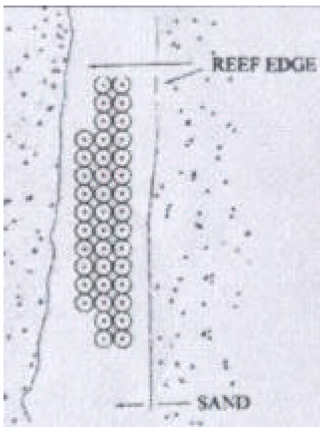


Figure 5. Large scale configuration of Reef Ball deployment. Each circle represents 30 m diameter. Each X represents one quad of Reef Balls. the Reef Balls will be deployed between two reef tracks.

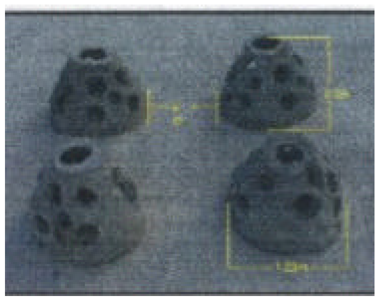


Figure 6. Model representation of a Reef Ball quad. Each individual Reef Ball will have 2 m separation from the other Reef Balls in the quad.

Coral Recruitment:

Settlement plates on each Reef Ball (Figure T) will be used to test hypotheses on enhancing coral recruitment through the use of larval attractants. The settlement plates attached to each Reef Ball wilt ire treated with a potential attractant (Iron, algal extract, coral transplants) and compared with control plates (no attractant). Coral transplants will be 4' cores drilled from large donor colonies (Figures 8 and 9). Eighty coral cores will be transplanted onto the Reel Bell modules (forty cores of each of two different species). Control corals occurring on the natural reef, and of comparable she to the donor corals, will be monitored for comparison of growth and mortality.

Larval Attractants: Each individual Reef Ball in a quad will incorporate one of four different attractants on the settlement plates.
Iron additive « » Algal extract
Coral transplants « » Control

Figure 7. Reef Ball with settlement plates. Each Reef Ball will have two adjoining settlement plates. Settlement plates have smooth and rough surfaces to investigate the effects of surface texture on the preferential settlement of coral recruits. Each individual Reef Ball in a quad will incorporate one of four different attractants on the settlement plates: iron additive, algal extract, coral transplant, or control.

Figure 8. Coring donor corals for transplantation. Eighty coral cores will be transplanted onto the Reef Ball modules (forty cores of each of two different species).

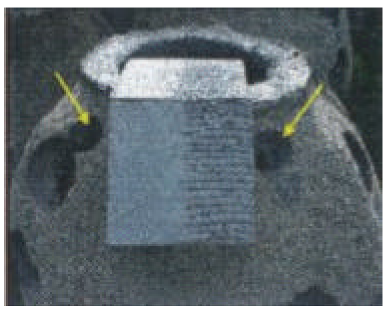


Figure 9. Transplant Reef Balls will hold one core of each species (Montastrea cavernosa or M. faveolata and Diploria clivosa). Coral transplants will be placed in the pre-fabricated transplant holes adjacent to the settlement plates (yellow arrow).

Coral Transplantation and Monitoring:
At quarterly intervals the donor corals, coral transplants, and control corals will be visually assessed to provide information on individual colony health, growth, and mortality.

Fish Recruitment:
The 40 quads will be divided into 4 different levels of structural complexity to test the hypothesis that multiple refuge size and the resultant diverse fish assemblages may affect coral recruitment, survival, and growth. One set of 10 quads will have the void space of all the Reef Balls filled with large refuge structure (Figure 10). One set will have the void spaces of all filled with small refuge structure. Another set will be mixed and have one Reef Ball empty, one with large refuge, and the last two with small refuge. The final set will have the void space of all the Reef Balls empty. The assemblage or fishes (species, number, and size) associated with each quad will be recorded every three months by visual census (Figure 11).

Structural Complexity: Each type of fill will be used for 10 quads.

- Large fill - 4 concrete blocks to each Reef Ball of the quad.
- Small fill - ¾" plastic mesh in each Reef Ball of the quad.
- Mixed fill - 1 Reef Ball of the quad with blocks, 1 empty and 2 with mesh.
- No fill - all 4 Reel Balls of the quad are empty.

Figure 10. Inside of Reef Ball with large fill complexity.

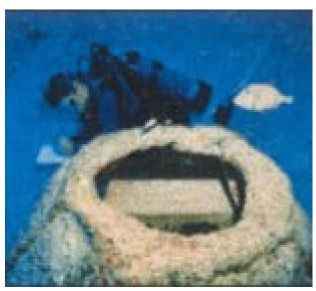


Figure 11. Diver conducting a fish survey on a Reef Ball displaying structural complexity of large refuge size.

Summary:

Artificial reefs are commonly used to provide structure to damaged reef areas. This project has been designed to use artificial reefs to not only mitigate for lost reef structure but to provide experimental platforms to examine several restoration strategies. The examination of these strategies will aid in making reef restoration decisions that involve: 1) the potential enhancement of coral recruitment through the use of coral larval attractants, 2) the effect of reef structure on fish assemblages, and 3) the interaction between fish assemblages and coral recruitment and survival.

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