INTRODUCTION

This paper deals with efforts on the part of the Aquatic Invasive Species Team to establish the range and eradicate the corallimorph *Actinodiscus nummiformis,* which was found in the Ala Wai Boat Harbor, on the island of Oahu in Hawaii (Figure 1). After several attempts over a period of three years and using a variety of techniques, we have successfully eradicated an introduced population. The corallimorph *A. nummiformis* is normally found in the Indo-Pacific and Red Sea (Carlgren, 1949).

This organism was first found in December 1997 by staff of the Waikiki Aquarium. The staff member was collecting samples for the aquarium, and noticed these organisms on the reef flat. The organisms were artificially attached to a piece of coral rubble, indicating that the organisms had been discarded from a salt-water aquarium (Coles 1997). It is believed that these organisms may have been intentionally planted for later harvesting, according to staff members at the Department of Agriculture. *A. nummiformis* and several other corallimorphs are very popular organisms in the aquarium trade, due to their iridescent colorful appearance.

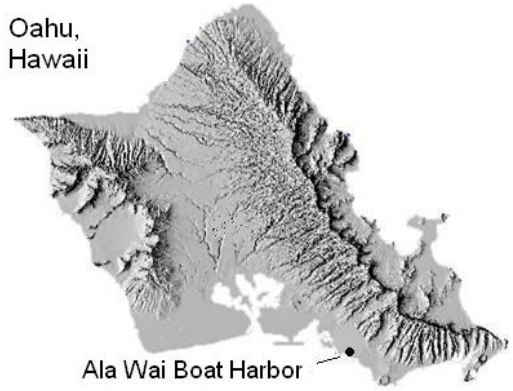

Fig. 1 Infestation location on the island of Oahu

Several efforts throughout the years have been invested in eradicating this organism, with various levels of success. These efforts were carried out by the State of Hawaii's Division of Aquatic Resources (DAR), and the Department of Agriculture. The impacted region was contained to a small area roughly 250 feet in length and 20 feet in width, along the transient pier of the boat harbor. The area is between the harbor break wall and the pier that runs parallel to this wall; the mouth of the harbor lies only several hundred yards away. The habitat of the organisms was an area of low light and poor water quality.

These organisms were difficult to remove, as they have soft tissue that attaches close to the substrate. They are also capable of pedal laceration as a mode of asexual reproduction, and use this method to expand proximally and radially (Miles 1991). When space limitations are presented, other species of this type of organism are known aggressors and have inducible aggressive structures, including marginal stinging tentacles and mesentery filaments (Miles 1991). If these structures are present, they can inflict damage to and possibly lead to the mortality of native hard and soft corals.

While there are no native corals located in the vicinity of the *A. nummiformis,* access to other coral reefs lie just outside the harbor. Due to the threat that these organisms can spread outside the harbor and have unmitigated access to the surrounding coral habitats, a method for total eradication and monitoring was determined.

MATERIALS AND METHODS:

This project began with an initial eradication attempt in 2002-2003 by DAR biologists. Two methods were used; manual removal and smothering. The organisms were first removed by hammer and chisel. When this method proved unsuccessful, smothering with a plaster of paris was tried. This was unsuccessful as well, but eradication efforts could not be continued at this time due to lack of manpower.

In May of 2005, this project was turned over to the Aquatic Invasive Species Team under the Division of Aquatic Resources. In the original eradication effort, *A. nummiformis* was documented in one section of the harbor, located between the transient dock and the harbor break wall. The harbor was explored, on foot, for habitats that contained similar characteristics; shallow water, substantial substrate, and adequate access to sunlight and water flow. The majority of the areas bordering the docks have steep slopes, with limited substrate, and poor visibility, which makes it unlikely habitat for this organism. The dock directly across from the transient pier, denoted by the numbers 700-799, had similar habitat characteristics within close proximity of the known area of impact. The area outside the break wall had similar habitat characteristics as well.

The second task completed for this project involved surveying these habitats and devising a method for accurately recording the locations of the organisms, for later removal. Initial data gathered during the surveys revealed that the organisms were confined to three small, separated spots along the transient pier and were not observed in any of the other locations surveyed. These spots were initially denoted by the corresponding slip numbers running parallel to their locations and included the space between slips 805 and 806, between slips 850 and 851, and between slips 854 and 855. They were designated as Area 805, Area 850, and Area 854. A total of forty-five distinct colonies were located within these sites; with Area 850 containing thirty colonies, Area 851 containing eight colonies, and Area 854 containing seven colonies. For our purposes we did not count individual polyps of the organism, but instead determined quantity by defining a colony as any group of organisms in contact with one another forming a larger mass. In some cases colonies consisted of only a few polyps, while in the largest colony there appeared to be dozens of polyps. Polyps were also of varying size.

Transect lines were established throughout each of the three project areas with a goal of minimizing the number of lines present, and to group as many colonies as possible within a quadrat. Each quadrat was assigned a numeric value based on its position along a transect line starting with the quadrat closest to the dock and heading toward the break wall. The numbers continue at the start of the next transect line. In all, a total of eight transect lines were established with a total of twenty-three corresponding quadrats. These endpoints of each transect was secured using twelve

inch spikes hammered into a solid portion of the substrate. Once these transect lines were established, photographic documentation was completed and a corresponding number was recorded, in meters, for the location of each quadrat.

Chiseling Method

Initial removal was performed manually by a group of divers in August of 2005. The eradication method involved chiseling the substrate containing organisms using high strength concrete chisels and four pound sledge hammers. As these organisms were sometimes found on soft sediment, loose rubble, and small rocks; chiseling was not always practical. In these cases the rubble and rocks were removed from the harbor and stored in large buckets on the dock. In cases when chiseling was necessary, an area around and including the colony was chiseled; this insured the organisms would experience as little disturbance as possible, to avoid fragmentation and spreading. After removal from the area, the buckets containing the organisms were filled with water and bleach to insure complete destruction of the organism. During this eradication effort, conditions became more challenging due to a rising tide and the disturbances caused by chiseling the substrate.

After our initial removal efforts, monitoring efforts, on a regular basis, were undertaken to determine the effectiveness of the eradication method employed and to determine if the organism was still present in this area. After several excursions, organisms continued to be encountered within our three project areas. These organisms were removed during these field activities in the same manner as prior removal efforts.

Monitoring efforts using transect lines and photoquadrats were eventually abandoned. As a result of dealing with organisms predominantly outside of our transect lines, time was invested in exploring the entire project areas on SCUBA. This allowed us to find and mark any organisms in this area without having to run transects. Establishing more transects to document these new colonies was determined to be impractical. This would have involved establishing as many transects as we had already installed. It was decided to mark each area containing organisms using GPS points.

Smothering method

Research into various other methods had been explored in the month prior, and several ideas as to smothering the organisms were discussed. It was determined that trying to cut water flow to the organisms by using sandbags may be a feasible method to eradicate these organisms. This method was decided upon based on the ease of securing these bags, as opposed to securing sheeting, tarps, or a similar system. Seven sites would need to be sandbagged to contain all of the organisms, roughly fifteen colonies, still present in our project site. Two areas were used to test this method. Sandbags were filled to capacity, and then shaped to match the contours of the substrate. Additionally, several large rocks were piled on top of the bag in order to disguise it and help insure that it remained secured.

The next step was to check the progress of the smothering method, after a three week interval, on the two selected sites. Following that check we installed the remainder of the sandbags in the five remaining sites. Additionally, a survey was

conducted within all project areas to determine if any organisms not previously recorded were observed. Upon visual inspection, it appeared that the colonies under both sets of sandbags were still intact, though no photographs were taken due to a camera malfunction. At this point it was decided amongst the team members that it would be practical to continue with the initial plan to sandbag the remaining five sites, at a minimum it would aid in containing the organisms until a better method could be determined. Before these sandbags were put in place, a large quantity of sand was placed around the organisms and then smoothed out to create a flat surface, devoid of cracks and crevices. This would provide a better seal between the sandbag and the substrate, and it would also provide more coverage with which to smother the organisms. This process was performed at all seven of these sandbag sites; marking pins that initially denoted the organisms' position were left in place. This would allow us to determine the exact location of the organisms once the sand was removed.

This was then followed by a later check, after three weeks, to determine if this refined method would contribute to the eradication of the *A. nummiformis* present. The sandbag test sites were photographed both from the surface and in the water before any work was completed.

RESULTS & DISCUSSION

In general, the chiseling effort reduced the large number of colonies, and the sandbagging method worked to eliminate the remaining small numbers of polyps.

The chiseling removal effort carried out in August 2005 reduced the number of colonies from 45 to 12 (Table 1). Those 12 colonies were removed, but 15 colonies were found during the next survey. Large numbers of colonies were found until the sandbag method was implemented (Figure 2). There are several possible reasons that organisms continued to be found. The visibility in this area was poor, especially when the sediment was disturbed. It is possible that organisms were simply not seen. They could have been too small to see. Some of the polyps were smaller than a pencil eraser; they could have grown to a detectable size between surveys. It is also possible that the organism was spread during the first eradication attempt; if there was fragmentation, the organism could have reattached. The first sandbag attempt on November 8th 2005 failed, but the second attempt on November 30th proved successful when 14 of the 18 colonies died.

Table 1. Number of colonies found and removed/smothered

Date	Colonies Present	Colonies Removed	Colonies Smothered	Colonies Remaining
5/12/05	45	0	0	45
6/24/05	45	0	0	45
8/9/05	45	45	0	0
8/16/05	12	12	0	0
8/26/08	15	0	0	15
11/8/05	18	0	7	18
11/30/05	18	0	15	18
12/20/05	5	0	5	5
12/23/05	5	4	1	1
12/29/05	6	0	0	6
12/30/05	6	6	0	0
1/5/06	1	0	1	1
1/20/06	0	0	0	0
1/24/06	0	0	0	0
2/8/06	0	0	0	0
2/16/06	0	0	0	0
2/23/06	1	0	0	0
7/3/06	1	0	1	1
7/19/06	0	0	0	0
7/27/06	3	0	3	3
7/31/06	1	0	1	1
9/1/06	0	0	0	0
10/4/06	0	0	0	0
10/31/06	0	0	0	0
12/13/2006	0	0	0	0
5/2/07	0	0	0	0
5/4/08	0	0	0	0

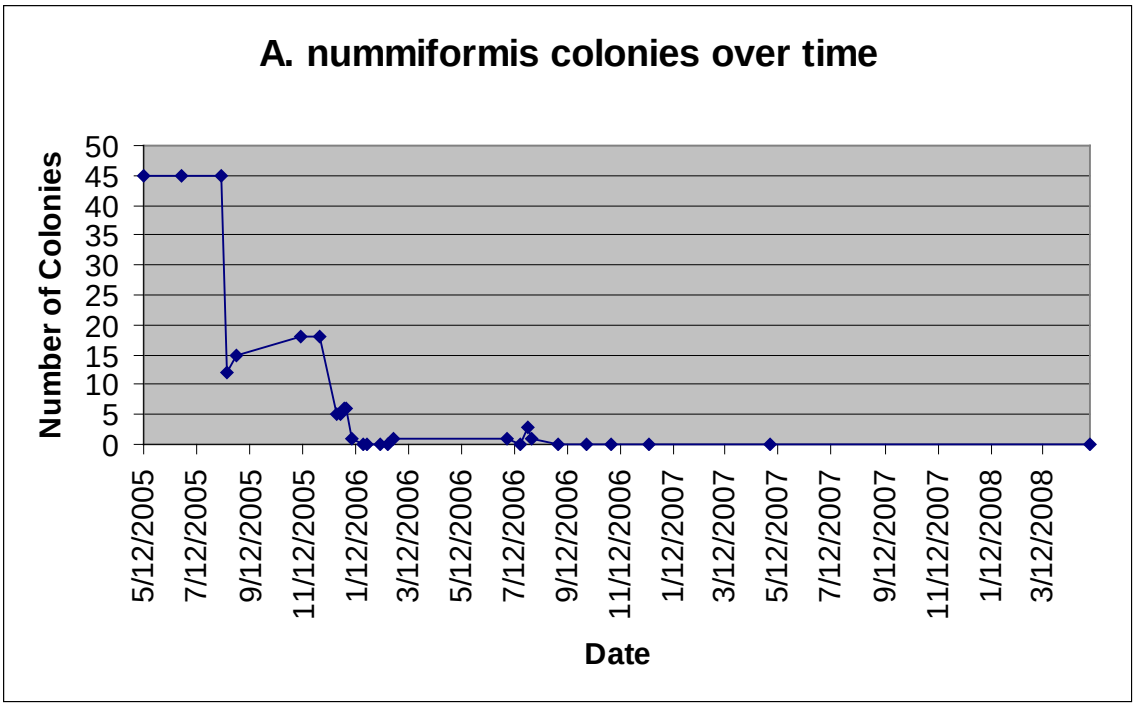

Fig. 2 Number of *Actinodiscus nummiformis* colonies over time

Surveys continued on a regular basis, with any organisms encountered being removed if attached to loose rocks, or smothered if attached to hard substrate. This proved to be effective in eliminating the small number of organisms that continued to be seen. Where these organisms continued to appear from is unknown, but poor environmental conditions may have played a role in them not being located during prior surveys.

This project was temporarily suspended due to a sewage leak at the project site, from March of 2006 to July of 2006, and when surveys resumed a small number of colonies were spotted sporadically and removed in the previous manner. No organisms have been detected since September 2006. The last survey was conducted in May of 2008, and no organisms were found, indicating a successful eradication.

There were several problems associated with eradicating this organism. Our biggest problem was the visibility. The substrate surrounding the organisms was very soft sediment. When disturbed, the visibility was immediately drastically reduced. This made further surveying and removal difficult. There is a chance that the original eradication effort may have spread the organism; if there was any fragmentation, the organisms could have re-attached, widening the range of established habitat. There were health concerns associated with this project. The small boat harbor and attached canal that fed the harbor were prone to frequent sewage leaks. During heavy rains, sewage was diverted into the canal, postponing the project. However, *A. nummiformis* was able to survive during this period, possibly thriving on the high nutrient levels.

Despite these setbacks, our eradication attempt succeeded for several reasons. *A. nummiformis* is a slow-spreading organism. Over a period of three years, it stayed

within an area of 50,000 square feet, and even then only in three discrete locations. On top of that, the infestation was in a relatively contained area. The suitable habitat was bordered by a break wall on one side, and a steep drop off on the other. These natural barriers kept the organism from spreading to outside the harbor. Another contributing factor is that we implemented two different removal methods. The chiseling removal effort helped remove the bulk of the organisms, while the smothering with sandbags allowed us to kill the remaining polyps. Through trial and error and a combination of methods, the Aquatic Invasive Species Team was able to eradicate the introduced corallimorph *Actinodiscus nummiformis.*

References:

Brockman D. (Undated) Disc or carpet anemones in the tropical marine aquarium. Aquarium Digest Intl. #32 Tetra

Carlgren O (1949) Corallimorpharia, Actiniaria and Zoantharia from New South Wales and South Queensland. Kungl. Svenska Vetensk. Akad. Handl. 1: 1-121

Coles S, Felice RC, Eldredge L. (1999) 0630 Nonindigenous Marine Species Introductions in the Harbors of the South and West Shores of Oahu, Hawaii 1997-1998, NODC_0000324: Bishop Museum Technical Report No. 15, Bernice P. Bishop Museum, Honolulu, HI.

Miles JS (1991) Inducible agonistic structures in the tropical corallimorpharian, Discosoma sanctithomae. Biological Bulletin (Woods Hole) 180:406-415