DRUM and CROAKER

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SHORT CONTRIBUTIONS AND ANNOUNCEMENTS

DRUM AND CROAKER 30 YEARS AGO

Richard M. Segedi

(From D. & C. Volume 15 (74) Number 1, Edited by John G. Shedd Aquarium)

Earl S. Herald, Director, Steinhart Aquarium 1948 – 1973, *George E. Lindsay*

The death of Earl Herald while diving off Cabo Sa Lucas on January 16, 1973 cut short the ebullient career of an outstanding aquarist. Earl was demanding of his employees, who were expected to share his enthusiasm, ambition, and dedication. He was also solicitous of their welfare, and protective and appreciative. "Graduates" of Steinhart hold many important aquarium positions in many places.

Earl S. Herald, April 10, 1914 - January 16, 1973, *James W. Atz*

Earl never lost an opportunity to boost the aquarium profession, and he constantly preached and consistently practiced inter-institutional cooperation. In 1957 he founded "Drum and Croaker" and served as the editor for the journal's first two issues. He was one of the nine original "Trustees" of the Aquarium Science Research Endeavor" (A.R.S.E.) and through the years, a leading participant in aquarium symposia, including the First International Congress of Aquariology, held in Monaco in 1960.

The San Juan Aquarium, *Robert A. Martin and Ernest Bodner*

Ocean Life Park Aquarium is situated atop a rise some thirty feet from sea level in the beautiful Boca de Cangrejos ("mouth of the crab") area which is just outside San Juan, Puerto Rico. It is surrounded on three sides by water: on the north by the sea, to the east by an inlet and to the south by Boca de Cangrejos Bay. This was the original site of the Battery Lancaster used in World War II, much of which still stands but has been incorporated into the aquarium. The aquarium building itself is actually the main building of the battery: munition chambers have been converted into large display tanks, the former machine room is an alcove where the small gallery tanks are located, and the base of the anti-aircraft gun emplacement is now the base of the dolphin tank. The aquarium is owned by Sea Aquarium, Inc. of Puerto Rico and has been in operation since 1971.

Sea World of Ohio Announces "World of the Sea" Triquarium

The newest of Sea World of Ohio's fifteen exhibits is the $1 million "World of the Sea" triquarium. The new three-roof complex which sets out over Geauga Lake features many of nature's highly unusual marine species. The artificial sea water for the exhibit will be specially formulated through the addition of 32 different chemical salts. This artificial sea water will then go through a month long curing process before any fish are put in the tanks. The water in each tank will be recycled every hour.

White Water, Blue Death, *Kym Murphy*

At Sea World of Ohio we [use] "break point" chlorination if the ammonia and nitrite levels in aquarium systems approached dangerous levels. ...[S]uddenly (at 3:00 A.M. - S.O.P. for aquarium emergencies) I received a call from the maintenance personnel stating that the exhibit had turned white and everything appeared to be dead (except for one loggerhead with a grunt in his mouth).

... [excess] sodium thiosulphate ions [react] with hydrogen ions to form SO_2 gas and elemental sulfur. The elemental sulfur colloid causes the system to turn white. The SO_2 gas, in solution, then reacts with water molecules to form H_2SO_3. The H_2SO_3 then combines with the dissolved oxygen in the system, bringing about the death of the inhabitants by asphyxiation.

OCCURRENCE OF THE JUMBO SQUID, *Dosidicus gigas,* OFF THE OREGON COAST: ITS CAPTURE AND LIFE IN CAPTIVITY

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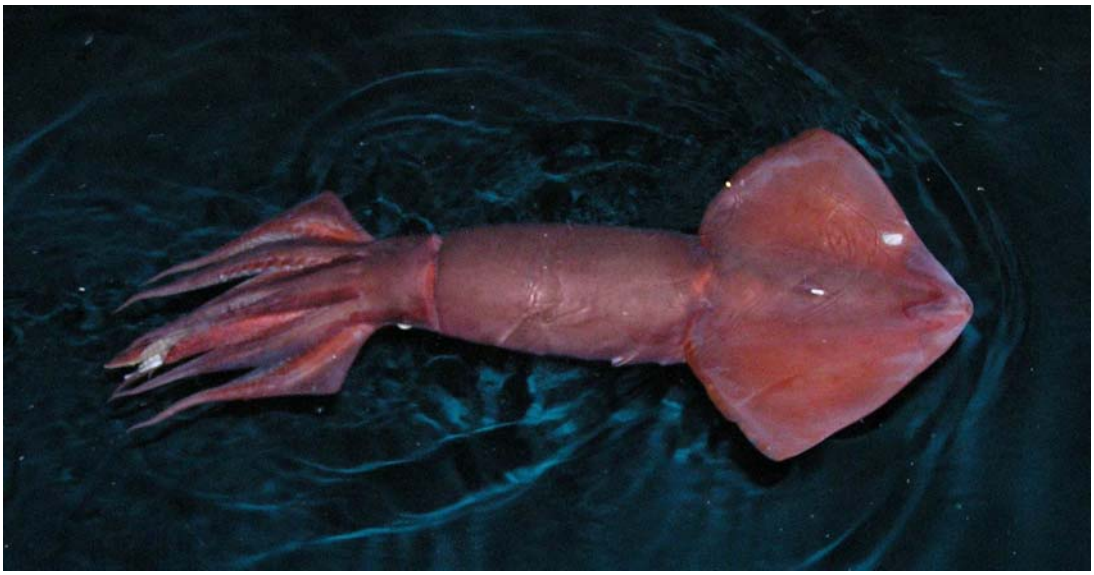
Abstract

The jumbo squid (*Dosidicus gigas)* distribution range is from San Diego, California to central Chile. The first reported catches of *D. gigas* in Oregon waters was in 1997, a very strong El Nino year. A specimen 114.3 cm and weighing 7.4 kg was caught on 28 October 2003 at approximately 0700 hours. It was brought to the Oregon Coast Aquarium where biologists observed it for four days until it died.

Keywords: Dosidicus gigas; jumbo squid; Humboldt squid; El Nino;

Introduction

The jumbo flying squid, *Dosidicus gigas* (d'Orbigny, 1835), is a large predatory squid that is an important fishery in the eastern Pacific. *D. gigas* are also known as the Humboldt squid because of their presence throughout the Humboldt Current in the eastern Pacific. Most of the commercial catch occurs between Mexico and Chile, with very little occurrence happening North of 30'N latitude. *D. gigas* are common between 30'N and 25'S latitude (Nesis, 1983) with the largest concentrations occurring off of Peru and Mexico including the Gulf of California (Ehrhardt et al. 1983). These large squid reach a maximum total length of 4m with the maximum mantle length being 1.5m and can weigh as much as 50 kg.



During El Nino events there are many changes to the physical and biological oceanographic processes along the Oregon Coast (Percy, 1999). *D. gigas* has been known to occur off of California during El Nino events (Seibel, 2003). The first record of this squid being as far North as Oregon occurred in 1997 which coincided with the last major El Nino (Pearcy, 1999). During the 1997 El Nino, bottom trawlers caught many jumbo squid between 43N and 45N latitude and between 124.5W and 125'W longitude (ODF&W, 1997). Also, hundreds were seen under deck lights in central Oregon waters 1997 (ODF&W, 1997) and 2003 (Ritter, pers. comm.).

There are very few records of people keeping captive jumbo squid. In 1998, the Bodega Marine lab kept a few *D. gigas* in captivity for brief periods of time. They were able to get one to feed, but it withered and died in a short period of time (Barrett, 1998). Since then, the Monterey Bay Aquarium has also made several attempts at collection and captive care (Welsh, pers. comm.). There are no records of anyone keeping one alive for more than a week. On 28 October, the Oregon Coast Aquarium was given a *D. gigas* to study.

Materials and Methods

On 28 October, Al Ritter and Jonas Fineman from the F/V Mickey donated a live *D. gigas* to the Oregon Coast Aquarium. The animal was caught on salmon trolling gear at approximately 0700 hours 12 nautical miles due west of Newport, OR, approximate latitude 44 38'N, approximate longitude 124 25'W. The surface water temperature where the squid was caught was 54°F. The animal was kept alive in an insulated 121.6 liter cooler with flowing salt water through the vessels deck hose. The squid spent 14 hours in that container until being transferred to aquarium personnel at 2100 hours.

D. gigas was transferred to our transport tank (456 liters) at the dock. The animal was then transported a short distance from the dock to the Oregon Coast Aquarium without water circulation or air circulation. The tank was hoisted up to the second story and into the square medical holding pool of the Open Sea exhibit. This area was chosen because it was the deepest holding area available at a depth of 3.05 meters, width of 7.34 meters and length of 9.15 meters. Total volume of the initial holding pool was approximately 204,667 liters. The transport tank was lowered into the water and *D. gigas* swam out of the tote with very little handling from the keepers.

Four foot long and two inch diameter PVC pipes with candy cane striping of duct tape were hung around the medical holding pool at two foot intervals to act as bumpers to visually assist *D. gigas* from the hitting the walls as it swam around the pool. Upon entry into the medical holding pool, *D. gigas* swam at the surface maneuvering well around the perimeter of the pool. It was very active despite its long trip and seemed very alert. It had a few scratches, but its appearance looked good. Pictures of *D. gigas* were taken to document its appearance. Light levels were kept low while its behavior was being observed. The lights were turned off at 2200 hours and kept off until the next morning at 0700 hours.

On the morning of 29 October, *D. gigas* was actively swimming around the pool along the walls. Its tail tip was slightly more irritated than the evening before, possibly from bumping

into the walls. At 0800 hours we offered *D. gigas* a sardine on a pole. It swam towards the sardine but was startled by a flash from a camera, and it darted away into a one foot deep skimmer box on the edge of the medical holding pool. This was the first time it had reacted to any camera flashes. The pole was held still, and after about a minute *D. gigas* slowly swam towards the sardine again as if it was hunting the sardine. It took the sardine off the pole and swam half way around the holding pool, then dropped it. The sardine had a one inch jagged chunk bitten off near its dorsal fin. Another sardine on a pole was offered. This time *D. gigas* did not show any interest in the sardine, so the sardine was placed on the squid's tentacles. *D. gigas* took the sardine off the pole and again swam half way around the pool before dropping the sardine. This sardine was intact.

At 0930 hours *D. gigas* was found resting in the skimmer box. It was coaxed out and the skimmer box was covered with a PVC pipe and conwebbing cover to prevent injury to the squid. At 1030 hours more food was offered. A herring was offered first. The jumbo squid took the herring off the pole, swam a few feet with it, and then dropped it. One small jagged chunk was bitten off the fish near the dorsal fin. Next a capelin was offered on a feed pole and placed near *D. gigas's* tentacles. *D. gigas* showed no interest in the capelin and actually pushed the fish away with its tentacles. Finally *D. gigas* ate one and a half market squid that were offered to it on the feed pole. The second market squid was bitten in half again leaving a jagged shaped bite. *D. gigas* is reported to feed mainly on other squids (Ellis, 1998).

At 1520 hours, *D. gigas* was offered another market squid on a feed pole. *D. gigas* quickly ate about two thirds of the four inch sized market squid. It seemed to be maneuvering around well. It stayed low in the water column and away from the walls. At 1545 hours the sardine, herring, and remaining squid pieces that *D. gigas* dropped were netted out. This activity from the keeper possibly resulted in a resting behavior of *D. gigas*. It hovered just an inch or two over the bottom of the pool. It held there very still with only a few tentacles moving slightly. This behavior was first observed while *D. gigas* rested in a strip of sunlight shining in the pool through an open door on the surface. After a few minutes, it moved to a darker corner and continued to hover very still. At 1700 hours *D. gigas* was actively swimming around the pool at the surface again. The lights were turned off at 1800hours and left off until the next morning at 0700 hours.

On 30 October at 0715 hours, *D. gigas* was actively swimming at the surface. It seemed to be avoiding the walls, but its appearance was a little worse than the day before. At 0800 hours *D. gigas* was resting at the bottom of the pool hovering just above the bottom of the pool. A squid on a feed pole was offered, but *D. gigas* showed no interest. The food item was taken off the feed pole by the keeper and dropped into the pool down to *D. gigas*. The food item landed in front of *D. gigas* and was pushed away with the tentacles.

Because of the short-lived captivity histories reported, the keepers at the Oregon Coast Aquarium made the decision to move *D. gigas* into a deeper exhibit for display. The exhibit chosen was the Halibut Flats exhibit which is 26 feet deep, approximately 300,000 gallons, and houses halibut, flounders, skates, sablefish, lingcod, and a variety of rockfish. This decision was made for two reasons; to give *D. gigas* more room to swim around and to give the public a

chance to view this unique and rarely seen animal in captivity. At 1030 hours the *D. gigas* was caught by coaxing it with a net into a stretcher. It was resting at the bottom of the medical holding pool before the capture. *D. gigas* was transferred to the Halibut Flats exhibit about twenty feet away from the Open Sea medical holding pool. It was released from the stretcher directly over a viewing tunnel. First the *D. gigas* swam into a lingcod's territory and was chased by the lingcod over to the other side of the tunnel. There was no physical interaction between the lingcod and the jumbo squid. Next the *D. gigas* was briefly chased by a sablefish and a yelloweye rockfish. The yelloweye rockfish bit the jumbo squid's tentacles several times. Immediately after this interaction, *D. gigas* was captured at the surface in the stretcher and moved back to the medical holding pool. *D. gigas* was on display for less than ten minutes. At 1400 hours six juvenile shiner perch *Cytomatogaster aggregata* were put into the medical holding pool to entice *D. gigas* to eat. However, *D. gigas* did not go after consume any live prey.

D. gigas lived in the holding tank periodically swimming and resting until the morning of November 1, 2003 when it was found dead. During its last day it did not eat.

Discussion and Conclusion

The Oregon Coast Aquarium wanted to use the opportunity provided for us to learn whatever we could about this animal both as an individual in our tank and as a species in our local waters. Prior to 1997 *D. gigas* had not been found much north of Monterey, CA (Hochberg, pers. comm.). The occurrence of this animal so far north poses many questions. Is their occurrence due to an El Nino oceanographic situation? *D. gigas* have planktonic larvae that are subject to ocean currents (Rodhouse, 2001). Is their occurrence due to a booming recruitment year, a cycle? Migrating squid invade coastal areas of the northern (western USA) and southern (central Chile) peripheries of their range in years of high abundance (Nigmatullin, Ch. M. et al., 2001). Is their occurrence due to *D. gigas* expanding their range? There is evidence of this ecological opportunist, *D. gigas* taking advantage of reduced competition from collapsed ground fish stocks and moving into fill in niches (Caddy and Rodhouse, 1998). The reason they arrived this far North is quite complex. This is the second time in seven years that large numbers have come close to shore in central Oregon. It is beyond our scope of knowledge and this publication to answer these questions, however; we wanted to share with the aquarium world the husbandry steps we took while this specimen was at the Oregon Coast Aquarium.

D. gigas are large animals that generally live at great depths, believed as deep as 2,300 feet (Lovgren, 2003). Captivity might not be easily achieved. We have not talked with anyone that has had much more success than then we did. We believe that like most pelagic animals, tank size is a big factor. Unfortunately, not too many aquariums have a large tank of 2 million liters that isn't already filled with large predatory fish. A dedicated habitat would most likely be necessary for these animals.

Capture of this animal would be best done at night when they could be attracted with light and perhaps scooped up and placed in a dark confined holding tank. Temperature of transport and tank water might be better if chilled to slow metabolism. Perhaps with refined methods and dedicated materials, this stress factor could be greatly reduced, and our captivity

duration could be increased.

Currently the Monterey Bay Aquarium is attempting collections of *D. gigas*, using various methods and holding systems (Welsh, pers. comm.). We wish them the best and hope to join them if *D. gigas* frequent our waters more often in the future. Our specimen will be preserved for education and samples will be taken for any researcher looking to do any genetic analysis.

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VITAMIN C, AN ALTERNATIVE TO SODIUM THIOSULFATE FOR BLEACH NEUTRALIZATION

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Abstract

In answer to a puzzle presented to us by one of our aquarists, studies were conducted on the effectiveness of Vitamin C (ascorbic acid) as a neutralizer of chlorine bleach used in common sanitization procedures. Vitamin C was found to be as effective as sodium thiosulfate (the most common de-chlorinator used in husbandry practices at the Monterey Bay Aquarium) at neutralizing chlorine. A slight decrease in pH is observed with the use of Vitamin C. However, this can be compensated for by aeration of the seawater or by the use of the pH-neutral form of Vitamin C: sodium ascorbate.

Introduction

During the normal operations of aquariums or aquaculture facilities it is sometimes necessary to sanitize seawater. Chlorine bleach is commonly used for this purpose. While highly effective at killing pathogenic organisms it is also toxic to more desirable aquatic life. Thus chlorine must be neutralized before re-introducing animals to a sanitized system or before discharging this water to a sensitive habitat. Sodium thiosulfate is widely used to neutralize residual chlorine. The advantages of this chemical are that it is effective, inexpensive, and has a known history of use in aquatic operations. However, it is a sulfur based chemical which can lower dissolved oxygen levels and when used in excess may encourage the growth of thiobacillus and other bacteria (Tikkanen et. al, 2001). Considering today's environment of increased discharge regulations and required monitoring, is there an alternative to sodium thiosulfate that may be a better choice from an environmental perspective?

These were questions we decided to explore when one of our aquarists came to us with a story about a local shrimp farm using Vitamin C to de-chlorinate their sanitized tanks. He asked us if we thought Vitamin C may be an effective alternative to sodium thiosulfate for use in our sanitization practices at the Monterey Bay Aquarium (MBA). A literature search revealed that Vitamin C is used to de-chlorinate municipal water (Peterka 1998, Tikkanen et. al, 2001) and water used in kidney dialysis (Wiseman, 1997). With this positive information we decided to further explore the use of Vitamin C in our operations.

Two studies were conducted to test the effectiveness of Vitamin C versus sodium thiosulfate at neutralizing chlorine. In addition, biological comparisons were made between phytoplankton grown in seawater neutralized with sodium thiosulfate and in seawater neutralized with Vitamin C. However, for the purposes of this article we only present data from our more

recent and more thorough study. Please contact us if you would like some additional information on either set of experiments.

Materials and Methods

Chemical Experiments:

Does Vitamin C even work as a neutralizer of chlorine and how much should we use?

Two sample sites at MBA were chosen based on their organic loading. We used Penguins Exhibit water for a high bio-load sample and Jellies System water for a low bio-load sample. Samples were taken from each system and the initial pH of the seawater was measured. Each sample was sanitized using the current MBA protocol of 0.5mL of standard household bleach (5.25% sodium hypochlorite) per 1L of seawater**.** After sanitization the pH was again measured and free and total chlorine levels were determined using the Hach DPD method. Sub-samples of 100mL each were stored in capped 250mL Erlenmeyer flasks until being neutralized with a dose of Vitamin C or sodium thiosulfate. To determine the best neutralization dose the de-chlorinators were added at 5mg dose increments from 0-70mg per 0.5mL of bleach used. The pH and free and total chlorine residuals were measured for each de-chlorinated sample. Multiple replicates of each de-chlorinator dose were run to provide an estimate of the variability of each measurement.

Biological Experiments:

Will using Vitamin C as a de-chlorinator affect the health of our exhibit animals?

Nannochloropsis oculata, a small green alga often used to feed exhibit animals, was the organism chosen for the biological experiments. This alga is one of the few organisms routinely grown in sanitized and neutralized seawater at MBA. Phytoplankton growth curves were compiled for three different treatments of seawater. The first treatment was a control of autoclaved seawater, which is used routinely for primary phytoplankton cultures. Larger batch cultures are grown in bleached and neutralized seawater. The second treatment was bleached seawater neutralized with sodium thiosulfate. The third treatment was bleached seawater neutralized with Vitamin C. Each treatment included three replicate flasks, each containing 300mL of treated seawater. The pH and chlorine levels were measured before and after treatment. Each flask was then inoculated with 10mL of stock algae culture and supplemented with 0.3mL of Micro Algae Grow (Florida Aqua Farms, Dade City, FL). Daily samples were taken from each flask and fixed with Lugol's iodine prior to counting. Triplicate cell counts from each flask were made using a haemocytometer. The mean and standard error was calculated for each treatment and these data were used to generate growth curves.

Results and Discussion

Residual chlorine was effectively neutralized with a dose of 50mg of sodium thiosulfate or 60mg of Vitamin C for every 0.5mL of household bleach used (Figure 1). This equates to 0.8lbs of sodium thiosulfate or 1lb of Vitamin C for every gallon of bleach. Our experiments with high and low bio-load water revealed no significant differences in the amount of neutralizing chemical required. However, our high bio-load water is not especially high in organics when compared with other aquatic facilities. It is possible that less neutralizing chemical may be needed for water with a very high organic load.

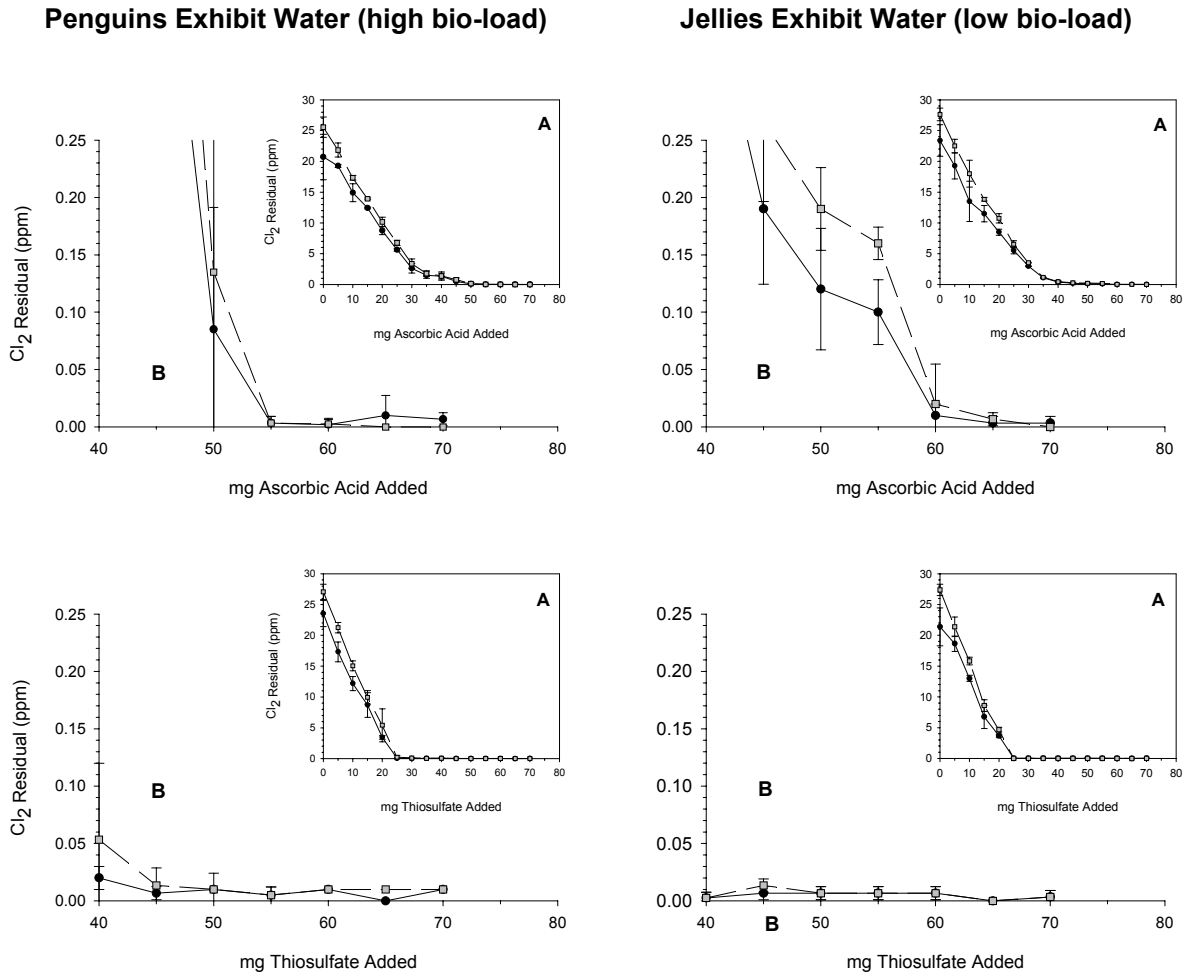

Figure 1. Mean ± standard deviation of free and total chlorine residuals after the addition of specified amounts of either sodium thiosulfate or ascorbic acid to bleach sanitized Penguins Exhibit or Jellies System seawater. Shown are all neutralizing doses tried (A - inset) and those doses near complete neutralization (B).

The addition of bleach raised the pH of our seawater samples by about 0.5 units. At the neutralization dose of sodium thiosulfate the pH returned to normal levels of about 7.6. Vitamin C is a weak acid so at the neutralization dose the pH of the seawater was depressed to about 7.0-7.2. This drop in pH could be compensated for by aerating the water with an air stone for a couple of hours (the actual time would be dependent on tank volume). Another alternative would be to use the pH neutral form of Vitamin C: sodium ascorbate**.** In fact, out of eight chemicals they tested, including sodium thiosulfate, Tikkanen et. al, (2001) recommended the

use of sodium ascorbate for use in de-chlorination because of its minimal impact on water quality.

Nanochloropsis oculata growth curves showed no significant difference (P>0.05) between the growth of phytoplankton in the bleached and neutralized treatments versus the autoclaved seawater control (Figure 2). However, growth of phytoplankton was slightly faster in the Vitamin C treatment than in the sodium thiosulfate treatment. The P-value was <0.05 at multiple data points on the growth curve. In addition, the 95% confidence intervals of the slopes of the two graphs do not overlap, indicating faster growth in the Vitamin C samples. This indicates that sodium thiosulfate may act as a slight toxin and Vitamin C may be a healthier alternative.

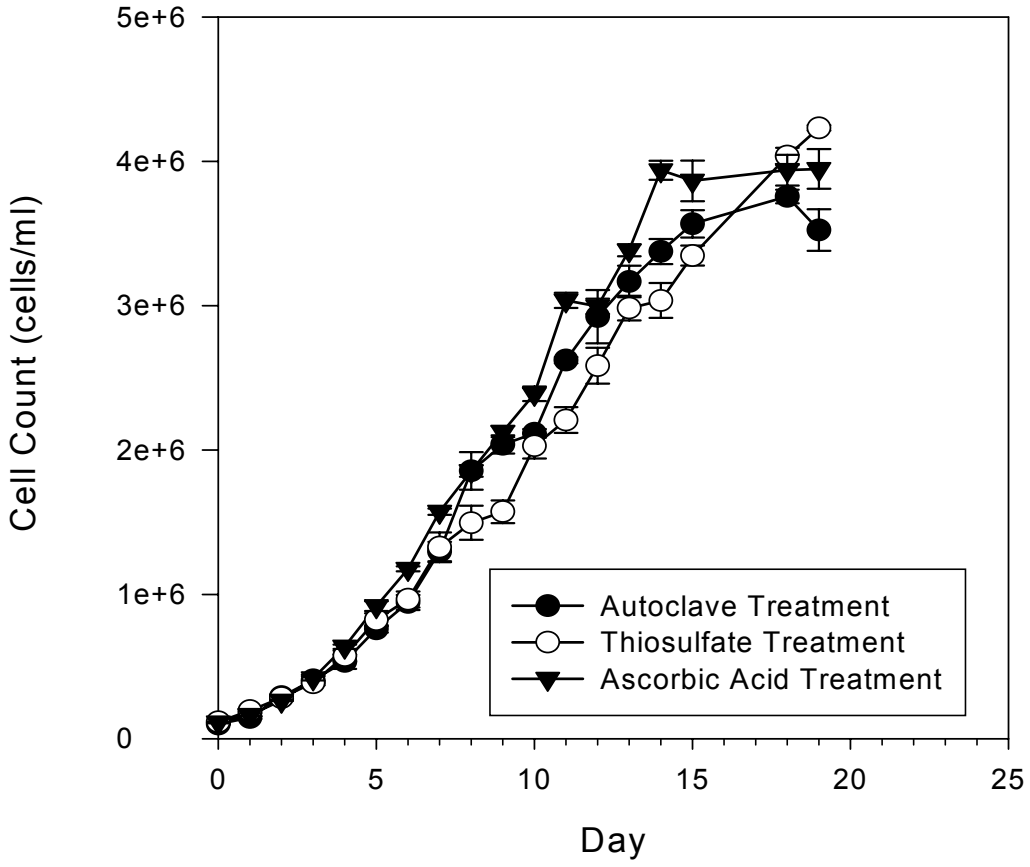

Figure 2: *Nannochloropsis oculata* growth curves for three seawater sanitization treatments. The curves represent the mean ± standard error of triplicate cell counts from three flasks per treatment.

The use of Vitamin C may be further encouraged by the increased environmental regulations being imposed on marine and aquaculture facilities. In the Central Coast Region of California a new General National Pollution Discharge Elimination System (NPDES) permit is required for all aquaculture and aquarium operations (CRWQCB, 2002). Discharges of chlorine residuals are regulated, as are some of the potential impacts of de-chlorination on water quality. In addition, procedures to minimize the amount of pollutants entering the environment are required in the Best Management Practices plan that is submitted with the NPDES application. While not specifically regulated at this time, sulfur discharge may become an issue in the future. Vitamin C presents an effective option for neutralizing residual chlorine.

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OBSERVATION OF WHITETIP REEF SHARK (*Triaenodon obesus*) PARTURITION IN CAPTIVITY

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Abstract

At the Steinhart Aquarium a female whitetip reef shark (*Triaenodon obesus*) gave birth to four pups while under 24 hour video monitoring system observation. The birthing process is described for three of the four pups including the pup presentation at the adult cloaca through expulsion of placenta and umbilical cords. Included is a record of adult female parturition behavior during birthing, time of significant birthing processes and time of initial presentation of pups.

Introduction

Reproduction of placental and aplacental viviparous elasmobranches in captivity is becoming more prevalent (Uchida et al., 1990; Michael, 2001). However, there is a paucity of information describing captive elasmobranch parturition and accompanying behavior in detail. This paper addresses a normal captive parturition which could be used as an aid to guide husbandry and veterinary staff in what to expect before, during and after parturition both for the adult female and neonates. The birth would be considered normal because all pups were born alive and the female had no complications during birth.

A majority of captive whitetip reef shark parturition occurs overnight (Uchida et al., 1990; Garner, 1998). This means the observation of parturition is infrequent due to the low number of staff in facilities at night. Under these circumstances, the ideal way to observe captive parturition includes the following equipment: an underwater camera designed for low light, some low light over the tank and a video recording system.

A 24 hour underwater video camera system with 87 degree field of view (Subsea Video Systems, Inc, Elizabeth City, North Carolina 27909, USA) and a 24 hour time lapse video cassette recorder that imprints the date, hours, minutes and seconds on tape (Sanyo Electric Co., LTD., Japan, Model TLS-924) was professionally installed at the Steinhart Aquarium. The husbandry staff was able to observe a shark birth without human interference thanks to the installation of this underwater video monitoring system. The described observations and behaviors are a result of watching the recorded birth on camera.

Shark Transfer/Birthing Pool

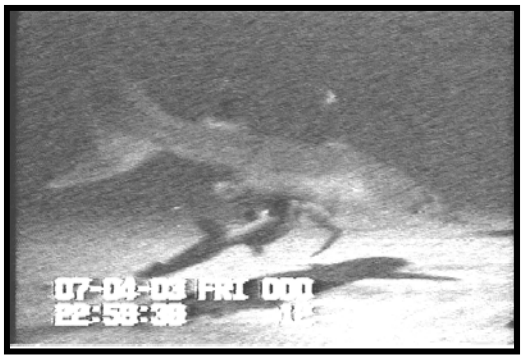
The decision that the female whitetip reef shark was gravid was made based on observed mating wounds from May 2nd to May 10th of 2002 and a subsequent swelling of her abdomen. Mating in the whitetip reef shark has been observed both in the wild and captive environments (Uchida et al., 1990; Tricas and Le Feuvre, 1985) and was determined to have occurred in this adult female due to open wounds seen on her gill slits and surrounding skin.

The female was caught from the main shark exhibit, transferred and isolated in a 44,000 liter pool on March 25, 2003 to prevent predation on the female and expected pups. The shark birthing pool was 6 meters in diameter and 1.5 meters deep. The water quality was maintained at 25.6 degrees Celsius with a pH of 7.1-7.2, salinity of 32-34 ppt and the water was tested for ammonia, nitrite and nitrate with no trace amounts detected. A set of five PVC pipes were placed in the tank in order for the pups to hide after the adult's parturition. On July 4th, 2003 the female whitetip reef shark gave birth to four well developed female pups.

Parturition Observations

At 10:38pm the female was observed swimming with a swollen, dilated cloaca and her anal fins noticeably farther apart. She was swimming at her normal speed and her condition remained the same until 10:45pm when she stopped swimming and lay down to rest, she was not seen resting again until after completion of the birthing process. At 10:47pm she resumed swimming and by 10:49pm the first sign of embryonic material was seen being eliminated from the cloaca. From 10:49pm to 10:55pm there were several occasions of the female twisting quickly, swimming in quick bursts of speed and occasions of body contortion resulting in hitting her abdomen on the pool floor.

At 10:53pm the first sign of a pup was apparent with the cloaca expanded to allow for the pup's caudal fin to protrude. The pup presented itself upside down with the ventral surface in contact with the birthing female's ventral surface. The pup's caudal fin and body continued to slowly protrude farther out of the adult's cloaca especially after bursts of visible torsion of her body. The female's behavior included some violent 180 degree turns, occasional bursts in increased swimming velocity and occasional physical contact with the pool bottom. At 10:59:38pm, the caudal, anal, second dorsal and pelvic fins were apparent (see images below).



At 11:03pm, the first pup was expelled with an accompanying quick patterned swim of the adult. The pup landed head first onto the pool bottom and within two minutes it began to swim. The umbilical cord and placenta were not attached to the pup. Both of the pup's pectoral and pelvic fins were slightly folded towards the pool bottom. The pup initially swam with irregular patterns mostly in the mid-water column. However, the pup's swimming quickly became more patterned with several minutes of swimming and then several minutes of resting on the bottom. The pup's behavior only changed when the female came close to it, then the pup swam quickly away from the female. There was no attempt from the female to consume the pup.

At 11:05pm the second pup became apparent at the female's cloaca with only the pup's caudal fin exposed. By 11:09 pm the second pup's caudal fin was exposed then with a quick movement the pup's anal fin and second dorsal became exposed. The chorionic membrane was seen trailing with the pup's caudal/anal fins from the birthing female's cloaca (the chorionic membrane looks like brown cellophane). At 11:10pm the female was contorting her body and shaking with very quick bursts of swimming speeds. On occasion she was observed hitting her abdomen and the exposed part of the pup's body onto the pool floor.

By 11:18:23pm the second pup was almost entirely hanging out of the birthing female's cloaca. The female continued to swim in occasional quick bursts, occasionally rolling on her side and hitting her abdomen and pup onto the pool floor (see left image). The female performed an abrupt 180 degree turn and at 11:18:39pm the second pup was born and landed onto the bottom of the pool. There was no initial attempt made by the pup to swim or avoid hitting the bottom of the pool. Within one minute the second pup was observed swimming with pectoral and anal fins folded slightly towards the pool bottom.

At 11:19pm the third pup's caudal fin was seen protruding from the cloaca. The adult continued to swim in clockwise circular patterns with less variation than previously observed. There were many occasions of her swimming out of camera view and she did not stop her circling for several minutes. At 11:23 pm the caudal, anal and second dorsal fins became apparent. Due to her swimming patterns the birth of the third pup was off camera and there was no observation of the actual birth.

The fourth pup's caudal fin and body were seen protruding at 11:32pm. The adult's behavior became repetitive almost pacing along the sides of the pool, although she performed a quick 180 degree turn. The pup was shaken and pushed farther out the cloaca during this turn. She did not appear to rub on the bottom of the pool, and her swimming direction did not appear to vary.

At 11:42pm the fourth pup was expelled from the cloaca entirely. The pup quickly fell to the pool bottom with no umbilical cord or placenta attached. The umbilical cords and placenta were expelled by the adult quickly after the pup was completely out of the cloaca. All pups were seen swimming at this time, the first three swam in a normal swimming pattern with fins more erect than previously observed. The fourth pup's head and caudal fin were lower than the dorsal areas and appeared slightly curled towards the pool bottom. The pup's body straightened out within one hour.

The female was removed from the parturition tank at 9:00am. The adult was reintroduced to the exhibit without sustaining injury upon reintroduction and began to voraciously feed within 24 hours. At 10:00am a physical inspection was performed on the pups:

they were sexed and an examination of their umbilical wounds was completed. The wounds were superficially open, but no blood, redness or remainder of the umbilical stalk was present. Tonic immobility did not occur, as they struggled even when turned upside down. They were identified by their spots, however, the spots did change in contrast within the next week; some spots became lighter, some became darker. The pups seemed healthy and began to feed on small pieces of fish within four days.

Discussion and Suggestions

Captive breeding of the whitetip reef shark has occurred in several facilities (Uchida et al., 1990; Garner, 1998) and is becoming a more common occurrence. This is due to the improvements in elasmobranch husbandry, tank design and nutritional requirements. If these trends continue, the reproduction of elasmobranches will inevitably need the support of shared communication about birthing cycles. The tendency towards cooperative learning and perhaps improved descriptions of parturition could lead to an increase of survival of adults and pups, not only during normal parturition but also during abnormal births. The more we recognize the trends in normal versus abnormal partition the easier it would be to make an educated decision as to whether there is a need to intervene.

In retrospect, there are a few improvements that could be made with the management of this animal and video system. There were a few times that the female was off camera due to the width of view; this could be remedied by installing a second camera or a camera with a wider lens. The 24 hour system worked for overnight observations, but there was an expected loss of video quality due to the time lapse system. The tapes are also constantly taped over (due to an automatic rewind system) and this also reduces video quality. The use of computer systems hooked up to the underwater camera that could record the video in digital format and saved for review might be more useful, if the computer has enough memory.

Acknowledgements

I would like to thank the Academy, aquarium husbandry staff, laboratory staff and engineers. A personal thanks to Paige Newman, Dean Do, Pat Morales, Dr. Freeland Dunker, Ken Howell, Tom Tucker, Miles Kenny, John Rampley, John McCosker, Subsea Video, all volunteers and volunteer divers.

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NELSON HERWIG RETIRES

Effective July 1, 2003 Nelson Herwig retired as Curator of Fishes from the Houston Zoo Aquarium after 25 years of service there. He served as consultant to the City of Houston in the design of the Aquarium there, and then was hired to oversee first the construction and then the operation of that facility.

Nelson is best known to the public aquarium community as the author of the *Handbook of Drugs and Chemicals Used in the Treatment of Fishes: A Manual of Fish Pharmacology and Materia Medica* (1979, published by Charles C. Thomas, Bannerstone House, Springfield, Illinois, 272 pp.). Before the invention of the internet by Al Gore <grin>, this was the only accessible comprehensive publication on fish treatments available to the public aquarist.

Prior to his service in Houston, he was Aquarium Supervisor at the San Antonio Zoo & Aquarium for nine years. Before becoming a public aquarist he was a geophysicist for what is now Exxon (then it was Humble Oil & Refining Co.).

Nelson says: “I am very comfortable in retirement and am catching up on a number of books that I have been in the process of compiling and writing for the past 30-35 years.... doing research on magnets and their application to aquaria... interesting stuff...” Contrary to occasional rumors otherwise, he also assures us that he is not dead.

HOW TO INSTALL A *Phyllospadix* PLANTER

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Abstract

Surf grass, *Phyllospadix sp*., is one of the few vascular plants to successfully find a home in the Pacific marine environment. It is found along the California coast and is abundant in the rocky intertidal, from the low intertidal zone down to approximately six meters. After our initial success culturing and exhibiting surf grass long-term in our Aviary exhibit, we developed a method for installing surf grass into our 335,000 gallon Kelp Forest exhibit. This new method, which includes site selection and fabrication techniques for a planter box, bungee cords, and attachment grid, has enabled us to grow and exhibit surf grass for nearly five years.

Introduction and History

Surf grass, *Phyllospadix sp*., is a marine flowering plant, emerald green in color, with narrow, flat leaves (1–4mm). It contrasts beautifully with the other intertidal colors of red, pink, and brown and forms persistent colonies along the rocky intertidal, ranging from the zero-foot tide level down to about six meters. Three species are found along the Pacific coast, however, only two, *P. scouleri* and *P. torreyi,* are found along the coast of the Monterey Bay.

Surf grass tends to grow in relatively horizontal areas with moderate to high water turbulence. The plants attach directly to rocks by adventitious roots that grow from a prostrate rhizome. Though nutrient absorption occurs at the roots as well as the blades, when the rhizomes are covered with sand, nutrients accumulate here and the roots may be more important in absorption than the blades. This sand burial leads to anaerobic conditions; however, there is an advantage in having aerobic and anaerobic environments simultaneously, as production is greater in these conditions than in a strictly aerobic environment. Anaerobic conditions are thought to act as a "nitrogen sink," reducing ammonia to nitrite and nitrate, which is very useful because surf grass can utilize dissolved organic nitrogen, ammonia, nitrite, and nitrate as a nitrogen source.

Although surf grass has been collected and displayed in many U.S. west coast aquariums, it was doomed to quickly fade to brown, and then dying in two to three weeks. In 1993, in our Aviary exhibit we were able to successfully culture and exhibit surf grass for the first time. Due to a wave generator, natural and supplemental lighting, and deep burial of the rocks covered with surf grass, the plants continued to grow and have even flowered numerous times since the initial installation. With the success of the surf grass in the Aviary, we were interested in attempting to grow surf grass in another exhibit, and thought our Kelp Forest exhibit offered the best possibility.

The Kelp Forest exhibit contains approximately 335,000 gallons of seawater that has a turn-over rate of roughly four hours. Large pumps forcing up to 1,200 gallons of seawater per minute directly from the Monterey Bay provide the correct temperature (on average, 54˚F) and essential nutrients. A specially designed wave machine generates surge throughout the display. The exhibit is a two-story concrete tank containing rockwork, ledges, reefs, and a back wall composed of fiberglass reinforced concrete. The top of the exhibit is open to the sky for natural light. Given these ideal conditions, we decided to install surf grass planters on various ledges in the exhibit, ranging from about four feet below the surface down to about ten feet.

Site Selection and Preparation

Planter sites were selected based on the following criteria: ledges were relatively horizontal, were less than 15-feet deep, were exposed to good water motion and natural light, and could be viewed relatively easily from the visitors' perspective.

Ledges were cleared of algal growth using cutting tools, wire brushes, and a siphon to expose the rock surface. Measurements were taken to obtain the length of the perimeter edge as well as the area within the planter site.

Fabricating the Planter Box Border

Gray or black Kydex™ was cut to the approximate length of the perimeter edge, and six to eight inches tall. The bottom edge of the kydex was left straight, while the top edge was cut with irregular curves so as not to be eye-catching. A heat gun was used to bend back a ½-inch edge along the bottom of the kydex at a 90-degree angle. Quarter-inch holes were then drilled along the ½-inch edge approximately every six to eight inches along the entire length of the kydex. The heat gun was also used to add bulges and curves and remove straight lines in the kydex to create a more irregular appearance. Acrylic paint could also be used to further camouflage the Kydex.

The trial fit was made by placing the kydex border along the planter ledge, verifying length, and trimming if necessary. The border was then secured to the front edge of the ledge using a continuous bead of Z-Spar™. The Z-Spar was pushed through the previously drilled holes along the bottom edge to increase contact area and provide an even more secure attachment. Dive weights were used to hold the border in place until the Z-Spar hardened.

Creating the Attachment Grid

Sections of semi-rigid plastic screening (Vexar™) were cut and fit into the flat, exposed area of rock inside the planter. Once again, Z-Spar was used to secure the screening in place at the corners and edges, leaving gaps in the middle to allow for plant attachment with bungee cords. This was allowed to harden before the final plant installation was made.

Fabricating the Bungee Cords

In order to secure the plants to the Vexar screening, bungees were made using one-inch PVC, ¼-inch surgical tubing, and zip ties (tie wraps). To create the PVC clips, one-inch PVC pipe was cut into ¼-inch lengths and a cut was made into one side of the PVC ring to form a C. Next, ¼-inch surgical tubing was cut into varying lengths, approximately eight to twelve inches.

Finally, the surgical tubing was secured to each PVC clip, using zip ties, to form the bungees.

Collecting and Installing the *Phyllospadix*

Numerous (6-8) large clumps of surf grass, *P. torreyi* and *P. scouleri*, were collected locally at low tide. To keep the plants moist and prevent them from tangling, bundles were carefully placed into a large, clear plastic bag and removed one by one during installation. Using the special bungees, each bundle was secured by attaching one PVC clip to the Vexar screen, stretching the surgical tubing across the top of the plant bundle, and attaching the second PVC ring on the other side of the bundle to the screen. This method was repeated until all bundles were secured and a large area of the planter was covered. To complete the planter, three to four inches of fine sand was added to completely fill the planter and cover all rhizomes at the base of the plants.

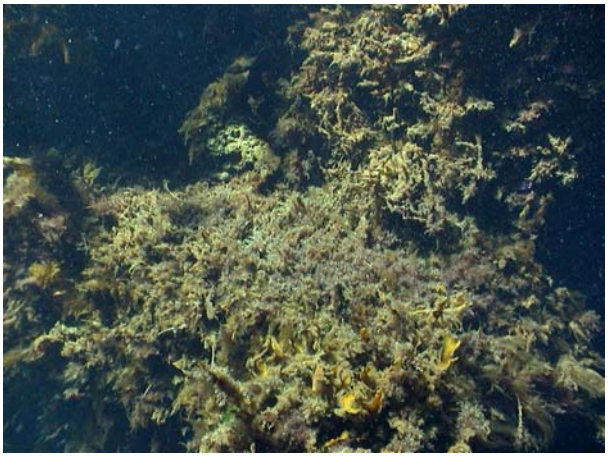

Figure 1. Site prior to installation of planter. Photo credit: F. Singer

Figure 2. Planter completed in 1998. Photo credit: T. Cooke

Further Considerations

Surf grass has grown successfully in our Kelp Forest exhibit for nearly five years. However, following the initial installations, we did notice a slight decline of some of the plants with numerous blades discoloring to brown and dying. This appeared to be a normal process following the transplants, and the remaining plants generally survived and continued to grow. We also noticed that it was necessary to replace some sand periodically after it washed away due to the surge and fish activity in the exhibit. Over time, natural algal growth and rhizome production covered the kydex border and gave the planter an even more natural appearance.

Surf grass provides not only color and diversity to our exhibits, but also lends shelter for juvenile fish. It is a unique and interesting plant, living in a fairly restricted zone, but also tolerant of wide environmental factors. It is also evident that there is an advantage in having aerobic and anaerobic environments simultaneously. Slow germination and growth rates may hinder captive growth, but the combination of wide environmental tolerances with as much

natural light and as much water motion as possible allows surf grass to grow and flourish in a captive environment.

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Figure 3. Planter completed in 2002. Photo credit: T. Cooke

Figure 4. Close-up inside planter. Photo credit: S. McDaniel

A NEW NATURAL FEEDING METHOD FOR THE REEF AQUARIUM

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Drum and Croaker Editor's note: This article was originally published in "Today's Fishkeeper", a UK aquatic publication, and it reprinted with permission from the editor, Derek Lambert, and the authors Pete Liptrot forwarded the article to Drum and Croaker on their behalf. The authors advise that this article is the result of their preliminary observations, not a true scientific study. .Italicized text in square brackets ([ ]) are further notes by PJM, Editor, D&C.

Introduction

From the very beginning of the captive care of marine animals within home, public and research aquariums to the present day, we have been feeding the animals contained in such systems incorrectly. This method of feeding results in many problems associated with the long term care of animals within a marine aquarium.

It is not the total amount of food that is the problem, which has previously been accepted in the past and blamed for poor water quality, but the manor in which it is delivered that causes adverse effects on the livestock and system.

We came to this startling conclusion after Dr Ellen Thaller's presentation at the WYMAG seminar October 2002, and the installation of a new and revolutionary feeding system in a marine aquarium, with outstanding results.

Dr Thaller described reef fish eating plankton at a rate of 50 - 60 pieces per minute all day. She then spoke of a food injection system in her fish-only research aquariums providing small quantities of small particle food continuously during the day light hours. Her results found a dramatic reduction in aggression between fish species and an increase in vitality and health.

We decided to develop this feeding practise and alter the food delivered and time scale to see the effects on a large system stocked with fish, motile and sessile invertebrates with a 98% hard coral stock.

We wanted to see the effects of continuous feeding in the aquarium but not solely aimed at the fish. We developed Dr Thaller's idea from feeding fish in the daylight hours to feeding continuously injecting not only fish food but coral food as well, with food injection 24 hours a day to facilitate the nocturnal feeding of some coral polyps, other sessile filter feeders and mobile invertebrates such as crabs and shrimp species. We also introduced a new food source to the aquarium, live phytoplankton, the oceans primary producer, to increase the zooplankton population, in an effort to develop a more natural food source. **In other words we are feeding the aquarium 24 hours a day 7 days per week.**

We looked at the effects of this food injection not only on the animals which we were targeting but also the natural population of life within the aquarium system. We also had to monitor the effects of this feeding on the filtration and water quality of the system.

Traditional Feeding Practices and the Problems It Causes to Both Livestock and Water Quality in a Marine Aquarium

With traditional feeding at two to three times per day and no nocturnal feeding the natural feeding patterns of our small reef fish, corals and other animals are altered, this has many detrimental effects on the animal, filtration system and its operation.

The effects of this feeding are vast, animals that have evolved to have a low concentration of food but continuously supplied are suddenly subjected to a gorge, starvation, gorge, starvation feeding regime. This sporadic introduction of relatively large amounts of food causes many problems:

1. Fish gorge themselves to collect as much nutrition as possible in a short time span, filling the gut with large unnatural amounts of food.
2. Large amounts of food remains partially or undigested within the fish gut and is passed as faeces, only a small proportion of food is assimilated through the gut wall. This represents a huge loss in the animal's potential energy budget and an increase in contamination to the aquariums water body.
3. The animals are then starved with only natural food to eat existing at a very low concentration. Over time the fish's health can suffer as they begin long term malnutrition. This results in a loss of vitality, high rate of disease, infection, and a high mortality rate.
4. Fish behaviour is altered as they become unnaturally aggressive to species they would ignore in their natural environment.
5. Large amounts of microscopic particulate food is lost to the system, most will reside in the boundary layer existing over the solid/ liquid interface of the rockwork within the aquarium. If not eaten by scavengers this then can rot down causing pollution and possible algal problems.
6. Filter feeding foods are often added in too small amounts once per day, resulting in rapid increase and rapid decrease in food concentration to the animals.
7. Corals and other Cnidarians suffer as their food source is sporadic. A surge in amino acids stimulate their feeding responses but is often to late as the main bulk of particulate food has been taken out of the system by filtration, or eaten by other animals, by the time the corals have extended their polyps to feed.
8. No food is added during the night, many animals including corals and other filter feeders are active during the night. They rely in the capture of natural nocturnal zooplankton within the aquarium, whose populations remain low due to low food source and predation. Nocturnal feeders are slowly starved.
9. For Cnidarians less food is assimilated, resulting in less waste production, this waste is food for the symbiotic algal population within the gut wall, this results in a lower algal population within the coral, resulting in low algal waste such as sugars required by the coral as food.
10. Lower algal activity results in lower growth rates of the corals, and lower calcification in the growth of hard corals.
11. Again long term malnutrition acts upon the animals resulting in weaker animals which lowers the vitality, and increases the disease and mortality rate.
12. Denitrifying bacteria populations and activity fall and rise to the availability of their food source, this source again has high peaks and low troughs due to the feeding. As a surge in toxins appears the bacteria are slow to respond, this results in a high residence time of toxins in the system. Even at low concentrations the toxins are acting on the metabolic processes of the

13. Aquarium inhabitants further increasing the biological stress levels.

So it follows that if we can feed our captive animals in a way in which they have evolved to feed, this would result in healthier animals, higher growth rate, less disease and mortality. What we had to do was devise a way in which we could provide food for all the animals within the system as close to their natural requirements. Whilst increasing the food quantity yet not suffering a drop in any water parameter, thus maintaining high water quality.

The Aquarium, Filtration System, and Stock

The aquarium is owned and extensively maintained by a very good friend Mr Mark Howarth, in the North West of England who Co-authored this report.

The Aquarium system has a water capacity of 7,000 l and has been in operation for 8 months; however the filtration system is 2 years old. The aquarium has over 1200 kg of live rock, over 100 fish ranging from a 20 cm naso tang, *Naso lituratus* to a shoal of *Pseudanthias ventralis* 2.5 cm long, around 300 hard corals about 200 small-polyped stony corals and 100 large-polyped stony corals, anemones, gorgonians, worms and countless crabs and shrimps.

The aquarium is lit by seven 400w 10,000K metal halide luminaries and a custom built light computer by Aqua-Medic and five D & D Aquarium Solutions T5 pendant units each with six 39w Actinic tubes , with a moonlight all under computer control. All lamps are from Arcadia.

Water circulation is via twelve IKS turbo 3500 pumps with a 40% reduction in power during the night. Temperature is controlled via a plate heat exchanger, air conditioned aquarium room and a chillier. The filtration consists of an Aqua-Medic denitrification unit, two Deltec fluidised bed calcium reactors running 12 hours per day (turned off during the night), injection of ozone only when the redox potential fall below 450 (very rarely used), Deltec AP1006 protein skimmer with a self cleaning head, algal refugium reverse lit with a 150w metal halide, phosphate control via a Deltec fluidised bed Rowaphos reactor, and a Deltec Kalkwasser stirrer, dosing at night only. UV sterilisation is not used.

Iodine, strontium, and various trace elements by HW Aquaristic are dosed under computer control every 4 hours. Salinity is kept constant with an automatic top up system, and 20% water changes using HW synthetic marine salts are performed once per month. Total water turnover is at the rate of 64,000 litres per hour.

All water parameters in both the sump and main aquarium are monitored via two IKS professional computer systems with the general parameters at the beginning of the feeding being: Salinity 1.026, Temp 26 Celsius, pH 8.2 - 8.4, Calcium 420ppm, DKH 8, Alkalinity 3.3, Magnesium 1420ppm, Iodine 0.06, Nitrate 20ppm, Redox potential 450, and phosphate, nitrite and ammonia 0.0.

Feeding

As we wanted to feed during the night time hours, after much discussion we decided to increase the total food given to the aquarium. We had also decided to add a totally new food source, live phytoplankton to the system in an effort to increase the natural zooplankton population, facilitating another increase in food injected to the system.

The existing feeding was as follows:

All food listed here was the total food injected to the system in a 24 hour period, fed twice per day half in the morning the other half in the evening. *["Injected" in this case appears to refer to the act of adding food by hand to the system in the traditional manner, not the use of the continuous feeder described below. This is list of foods originally added to the aquarium before the experimental changes.]*

1 blister pack of San Francisco Bay Baby brine shrimp
1 blister pack of Aquafresh Cyclops
16 cubes of Gamma Omega 3 enriched brine shrimp
8 cubes of Gamma Mysis shrimp
4 cubes of Aquafresh chopped cockle
4 cubes of San Francisco bay chopped mussel
5 ml HW Multi Vitimin Complex
400ml of Marine Snow or Marine de lux alternating daily
San Francisco bay Seaweed Salad, green marine algae, 3 full sheets per day.

[The new feeding regime:]

We decided to mix up a two day supply of food in a container for the continuous feeding, the following were mixed together:

500 ml Marine Snow
500 ml Marine Deluxe
1 blister pack of San Francisco Bay Baby brine shrimp
1 blister pack of Aquafresh Cyclops
12 cubes of Gamma Omega 3 enriched brine shrimp
10 ml HW Multi Vitamin Complex
Then diluted with aquarium water to a volume of 2 litres.

This represented an increase of food by 200ml of coral food and mixing the two brands together as previously they had been fed on alternating days.

Twice a day the following was added to feed the larger fish in the aquarium:

4 cubes of Gamma Omega 3 enriched brine shrimp
8 cubes of Gamma Mysis shrimp
4 cubes of Aquafresh chopped cockle
4 cubes of San Francisco bay chopped mussel

This represented an increase of 4 cubes of brine shrimp.
The dried seaweed feeding remained unchanged.
4 liters of home cultured phytoplankton *Nannochloropsis oculata* over a 24 hour period. This was a totally new food source to the aquarium.

The Continuous Feeder

Equipment:

Aqua-Medic plankton reactor and peristaltic pump
Air-volution 2 air pump and air line
IKS Aquastar computer and 4 plug bar non variable

Method:

The food was placed into the plankton reactor and then the reactor was filled with aquarium water. The air pump was connected to the plankton reactor and air passed to mix and suspend the food mix within the reactor. Air line was passed to the base of the reactor with a bend at the bottom to avoid the stream of bubbles from the air inlet without any kink in the pipe. This air line was connected to the suction side of the peristaltic pump. Air line was connected to the pressure side of the pump and passed to the aquarium terminating above the outlet of an IKS turbo pump to ensure dispersal of food on introduction to the system. The pump was plugged into the IKS plug bar and the IKS computer programmed to switch on the pump every 15 minutes for 5 seconds 24 hours a day, 365 days per year. This timing allowed the peristaltic pump to deliver 20ml of food solution to the aquarium system every 15 minutes.

[To prevent spoilage, it would be advisable to keep the food mix cold (2-4˚C, 35-40˚F) using a small refrigerator or portable cooler.]

The remaining frozen food described was thawed in a glass of aquarium water and released into the aquarium in bulk twice per day. The seaweed was fixed to the side of the aquarium using a lettuce clip three times per day.

Phytoplankton Feeding

Equipment:

Cleartides fluidised bed filter
Air-volution 4 air pump, air line, 5mm ridged piping and air stone
Twin 54w Arcadia T5 starter and marine white tubes and reflectors.
Plankton culture and nutrients.
Salt water.
Peristaltic pump and digital timer.

One 2 meter high 15 cm diameter clear tides fluidised bed filter was modified by cutting down the centre pipe to a length of 30 cm. A standard air stone was attached to the end of a 5 mm ridged pipe was passed down to 10 cm from the bottom of the reactor in the middle of the cut down centre tube, and the air pump turned on. The reactor was filled with a fresh salt mix with a specific gravity of 1.026 at 26 Celsius. The T5 tubes and reflectors were fixed at opposite sides of the reactor and timed for 18 hours per day. 500ml of culture was added and fed with nutrients until dark uniform green culture was produced.

Air line was fed into the reactor and attached to the peristaltic pump; the terminal end of the air line from the pressure side was placed in front of the suction intake of the main return pump from the sump to the aquarium. The peristaltic pump was timed to deliver 333 ml of live phytoplankton over a twenty minute time span every 2 hours 24 hours per day.

The phytoplankton culture was topped up every day with fresh salt water mix and fed nutrients, we are currently looking to install a further 3 reactors to ensure an even culture density at all times, whilst reducing the nutrient content within the culture.

Results after 28 days of continuous food injection:

Water Quality improved even with the increase of food injected to the system all levels remained stable at the levels before the feeding commenced, only the nitrate level fell from 20ppm to 5ppm in 28 days.

There was no evidence of an increase in element depletion within the water body as expected with the increase in coral growth. We did not have to change any settings on the reactors within the system, or any dosing rates altered. *[The following changes were noted:]*

- Big increase in calcareous algal growth over the rockwork, aquatic equipment and glass was noted, with a distinct improvement in pigmentation.
- A zooplankton population explosion, with a conservative estimate being > 500% biomass increase within the aquarium and sump filter.
- Dramatic increase in coral coloration, polyp extension and growth rates, it is estimated that hard coral growth from the beginning of the feeding exceeded the growth for last three previous months.
- Distinct drop in fish aggression between established fish with new additions hardly recognised.

Discussion

We stress that we have no quantitative data on the changes apparent; however we can provide a theory with sound evidence to warrant on going experiments to collect such data. We also acknowledge that the time span is far too short to establish long term success but felt we had to release the study because of the magnitude of change involved. Much is still to be done and too much remains unknown, it is with this in mind we ask fellow aquarists not to attempt this on their home aquariums for the long term effects could prove to be negative.

We increased the total food injected to the system. Low quantities of food released continuously into the system allowed the fish, corals and other animals to regularly consume small particles, resulting in the following theories:

1. Nutrition assimilation through the gut is at a constant allowing an unchecked supply of energy.
2. Digestive enzymes levels within the gut remain constant to the food supply allowing a greater digestive ability to attack the food as it is passed through the gut, resulting in a more efficient nutrient assimilation less waste produced and released to the system.
3. Less food is lost as particulate waste as the fishes feeding behaviour changes from biting and fighting, to passively picking at pieces which can be swallowed whole and not bitten which release particles to the system.
4. We are hoping to show a drop in disease and mortality rate due to the increase of vitality within the fish and coral stock.
5. Corals and other Cnidarians are subject to a constant but low level of free amino acids 24 hours per day, this stimulation ensures a high degree of polyp extension facilitating a higher rate of prey capture.

6. The constant and higher supply of nutrients results in a steady rate of waste produced allowing the symbiotic algal populations to remain constant and at a higher density due to the increase in the supply of food.

7. This enhanced algal activity and nutrient concentration results in a greater growth rate of the coral.

8. There is less waste produced in the system, but what degree of waste there is remains at a much more constant level. This allows the denitrifying bacterial population and activity to remain constant to the food supply, resulting in a much lower toxin residence time within the aquarium water body. Therefore less stress is exerted on the biological functions of the animals.

9. The introduction of live phytoplankton acting in a synergistic manor with the new feeding during the night has boosted the natural planktonic populations within the aquarium. Most zooplankton species are nocturnal rising in the water column to filter phytoplankton or prey on those that do. The nocturnal feeding allowed a higher food source to the planktonic filter feeders facilitating a population explosion, the predatory zooplankton population followed. The constant supply of food allowed the predator prey populations to remain at a higher and dynamic level, we hope to sustain this level if not increase it, however too higher levels may prove detrimental to the system.

10. This increase in plankton biomass represents a huge increase in the natural food source of nocturnal filter feeders as many species of small-polyped stony corals are. Higher concentration and natural food source for these corals results in increased growth and vitality.

11. Other sessile filter feeding animals such as sponge, bryozoan and tunicate populations increase providing increased water purification and natural food source for others.

12. The motile benthic invertebrate population also exploded allowing a greater turnover of the sediment. Resulting in a cleaner substrate as detritus is formed and consumed at a constant rate, further reducing toxic waste production.

13. The increase in hard coral growth and calcium fixation rates within the system has not forced us to alter the calcium production rate from the calcium reactors, nor have we had to alter any element dosing rates. We feel this is a direct result in the increase of zooplankton predation providing those natural elements in a more natural form. Elements utilised and removed from the water body via biological pathways must come from somewhere, and we may well have to alter the dosing rates to maintain levels in the future. However the increase in benthic biomass and activity will provide an increase in acidic secretions acting on the surface of the calcareous substrate. This will provide an increased source of calcium and other elements to the aquarium water body, and may be contributing to balancing the increased demand.

14. We have achieved a nitrate level drop of 15 ppm yet we have increased the food levels introduced to the aquarium. High nitrate levels have mostly been associated with over feeding and high levels of waste. Even though we increased the food concentration we spread it over time, this resulted in more food being assimilated and thus less waste produced. Less food was lost as detritus and the detritus that was created soon became consumed by the natural populations of scavengers, only to recycle up the food chain within the aquarium, and not rot down. The introduction of live phytoplankton may also be responsible utilising nitrates as a food source.

With the cessation of starve/gorge feeding replaced with constant release of food into the system over 24 hours per day and a new food source, the base of the natural aquatic food web,

phytoplankton, a dramatic change has occurred to all life within the closed system. The problems associated with traditional feeding as previously discussed are dampened and every aspect of life within the aquarium is altered showing dramatic change in population dynamics within the planktonic, benthic, sessile and motile invertebrates. Hard coral growth, coloration and polyp extension increases, the fish are less aggressive and coloration has increased.

We have introduced 5 *Dendronephthya* species, a coral acknowledged to be impossible to keep in aquariums, to see if this new method of feeding will allow them to not only survive but grow in captivity.

To sum up we feel that this method of feeding allows energy to be transferred more efficiently through each and every pathway of the food web within the aquarium, resulting in an increase in the health of animals contained within it. Less biological waste produced as a result improves the water quality exerting less biological stress on the animals and a more efficient denitrifying bacterial population.

This short study may well prove to be further evidence that striving to create a near as natural environment for marine animals housed in a closed system is the way forward to increasing our success in the husbandry of such creatures.

RAW 2004

Mote Marine Laboratory (Aquarium)

The Regional Aquatics Workshop is an annual meeting of Public Aquarists from North America and many other parts of the globe. RAW # 18 will be the first to be held in Florida. Food events are planned for at least three evenings. The conference hotel is the Radison on Lido Beach.

Please note that the DATES HAVE BEEN CHANGED from the originally announced May 12-16. The NEW and CORRECT dates are given below.

DATES:

Wednesday, May 19-	AZA Aquatic TAG Working Meetings / RAW Icebreaker
Thursday, May 20 -	Paper Sessions: Conservation
Friday, May 21 -	Paper Sessions: Exhibit Innovation and Life Support Technology
Saturday, May 22 -	Paper Sessions: Remaining talks, Business Meeting, Aquarist Olympics
Sunday, May 23 -	Special Event: Tentative Trip to SeaWorld Orlando

HOST/CONTACT:

Kevin Curlee (kevin@mote.org)
Mote Marine Laboratory, 1600 Thompson Parkway, Sarasota FL 34236
Voice: 941-388-4441 Fax: 941-388-4312

TRANSPLANTING *Macrocystis pyrifera* IN THE MONTEREY BAY AQUARIUM

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Abstract

During a six-year period, live *Macrocysitis pyrifera* was routinely transplanted into the Kelp Forest Exhibit at the Monterey Bay Aquarium. Transplant techniques are discussed in detail. Statistical analysis of transplant longevity reveals a number of spatial and temporal differences in survivorship of the transplants.

Introduction

Giant kelp, *Macrocystis pyrifera*, is the cornerstone display species of the Kelp Forest Exhibit (KFE) at the Monterey Bay Aquarium (MBA). Giant kelp is a perennial brown alga in the order *Laminariales*. The largest and perhaps fastest growing marine alga, it is found off the Pacific coast of North America from Santa Cruz, California to the Baja Peninsula at depths from about 20 to 100 feet (Foster and Schiel 1985). A giant kelp plant is composed of a holdfast that anchors the plant to the bottom, and numerous fronds that grow to the surface. A frond consists of a stipe and many blades. The fronds are buoyed-up in the water column by small floats at the base of each blade (Figure 1). While fronds have an average life span of six to eight months, the entire plant can live up to seven years. A giant kelp plant is constantly producing new fronds near the holdfast to replace old senescent fronds in the canopy.

The Monterey Bay Aquarium has displayed live giant kelp since 1984. The 335,000 gallon KFE was specially designed to meet the requirements of giant kelp (Figure 2). Six large artificial rock reefs located on the bottom of the exhibit offer substrate for the plants to attach. The exhibit is 28-feet deep and open to the sky, allowing adequate ambient sunlight to reach the plants for photosynthesis. A wave machine located at the west end of the exhibit provides the water motion necessary for nutrient and gas exchange. The KFE receives fresh incoming seawater at a rate of 600 gpm and has a volume replacement time for fresh seawater of about nine hours. Under normal conditions, this turn-over rate provides sufficient nutrients for maintenance and growth of giant kelp. Water from the exhibit is also recirculated through a high-pressure sand filter at a rate of 1,000 gpm.

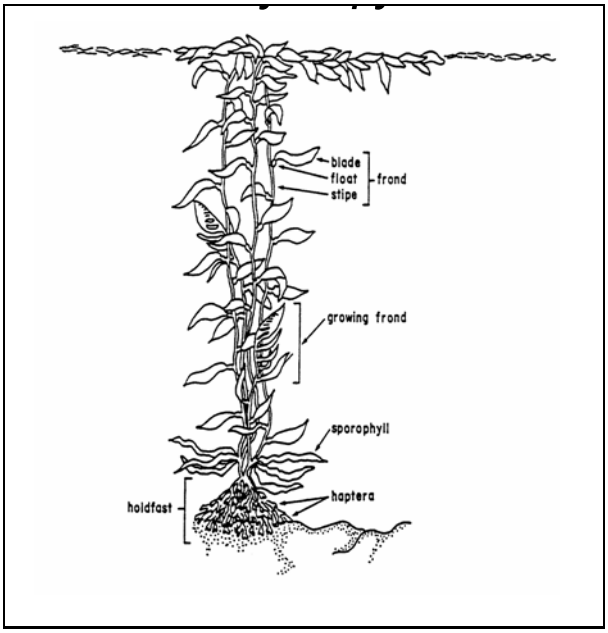

Figure 1. Giant kelp, Macrocystis pyrifera.


Figure 2. The kelp forest exhibit.

Over 70 species of algae grow in the Kelp Forest Exhibit. *Macrocystis pyrifera* tends to recruit quite well along the back wall and in places where there is good water motion. However, there are also 11 positions on the reef reserved for adult *Macrocystis* transplants (Figure 3). Acquiring these transplants entails collecting an adult giant kelp from Monterey Bay and transplanting it into the KFE.

Prior to transplanting, the giant kelp that looks unhealthy is removed and replaced with a new alga. Generally, the alga that has the fewest stipes, no young fronds or sporophylls at the base, and a lot of epiphytic growth is replaced first. Transplanting giant kelp is a day-long process that involves two dives; one to collect the adult *Macrocystis* and one dive to transplant it. Collections are scheduled regularly about every three months. Since *Macrocystis* tends to deteriorate in appearance over the winter and winter storms can dislodge many of the giant kelp as well as make it difficult to get out to collect them; an increased effort to replace aesthetically displeasing organisms is usually made in the early fall. Generally two to three collections are done from August to November. In addition, collections are scheduled whenever a particular transplant looked particularly unhealthy in comparison to the other transplants.

Methods

In order to do a collection and transplant, a small goody bag is filled with the following (Figure 4):

- Stainless steel screws
- Rock anchors
- Small hammer
- 2 screwdrivers
- Several pairs of different sized bungee cords (3-14 inches long) with one inch monofilament loops on each end

The following may also be needed:

- Pneumatic drill
- ¼ inch Drill bit
- First-stage regulator attachment
- Air tank

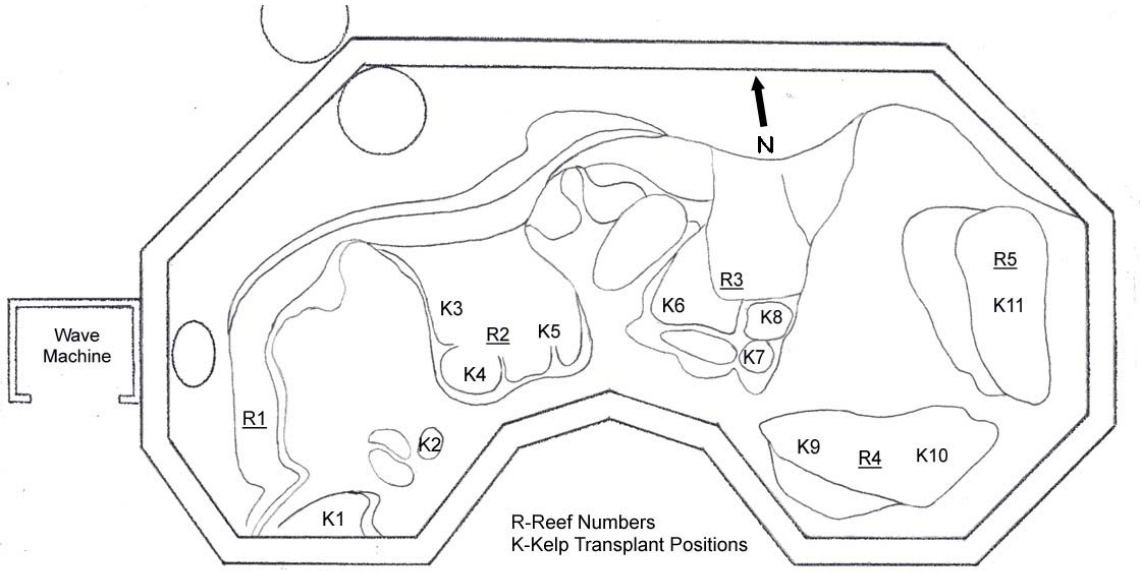

Figure 3. Kelp forest exhibit diagram.

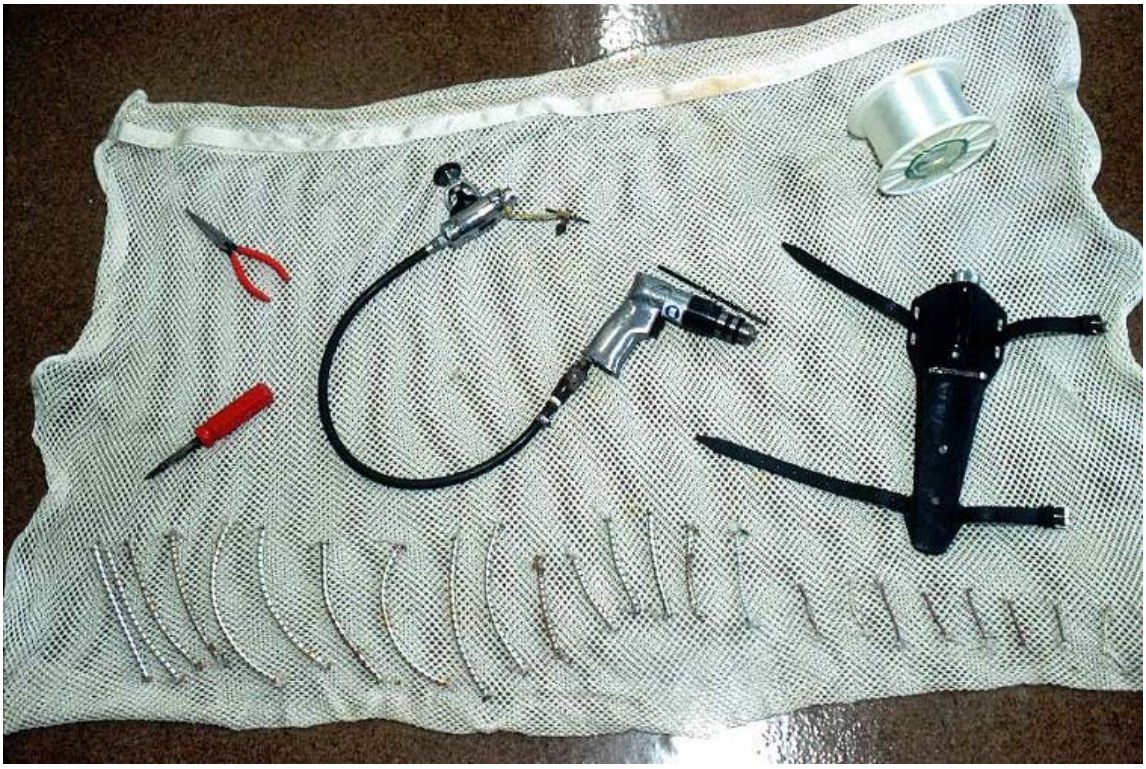

Figure 4. Materials needed for a giant kelp transplant.

The bungee cords are prepared in advance. They are made several at a time by taking a role of bungee material and stretching it. One inch monofilament loops are tied on using a bowline knot at measured increments along the bungee material. The material is then unstretched and cut to produce several different-sized pairs of bungee cords from about three inches to fourteen inches with monofilament loops on the end.

In the exhibit, the sites are usually pre-drilled with a number of screws that are anchored in the artificial reefs. A screw is placed in the rockwork by first drilling a hole with a pneumatic drill, hammering in a rock anchor, and then screwing in a stainless steal screw. These attachments are almost flush with the substrate and are not seen by visitors. There are enough attachment sites at each position so it is unnecessary to drill a new hole each time a new transplant is attached.

Collecting Giant Kelp

Macrocystis is collected on SCUBA from the Monterey Bay between 25 and 40 feet. A healthy plant with 10-20 fronds and numerous young fronds growing toward the surface is selected. The giant kelp should have a healthy holdfast about the size of a dinner plate and there should be no rot within the holdfast.

Once a good specimen is selected, one diver takes a long serrated kitchen knife and cuts the holdfast from the substrate well below the first dichotomy of haptera. Emergency camping saws have also been used successfully. While underwater, the alga is usually placed into an extra large mesh goody bag that was specifically made to hold an adult giant kelp. Getting the giant kelp inside the bag is often quite a challenge because the gas-filled pneumatocysts work against the divers' attempts to stuff the fronds in the bag. As the bag is filled it becomes more and more buoyant, and if divers are not negatively buoyant they can drift toward the surface with the kelp plant. During the summer kelp fronds can grow up to 200-feet long which produces numerous gas-filled pneumatocysts making the plant very buoyant underwater. When this is the case, giant kelp that have fewer stipes are collected or the buoyant alga is swam directly up to the surface to the boat on the surface. One or two plants can be collected on a dive.

Transplanting Giant Kelp

Upon return to the aquarium, the *Macrocystis* is placed in the KFE until it is transplanted. Generally, the adult *Macrocystis* is transplanted the same day as it is collected to minimize shock to the alga. The holdfast usually needs to be trimmed. Once the haptera are cut they will not re-attach. However, within a month, new haptera will usually grow out around the old haptera, onto the substrate, and attach the plant to the rock. Thus, extra bulk on the holdfast needs to be cut off. The holdfast also needs to be shaped so that the bottom of the holdfast fits securely on the substrate (Figure 5).

To install a new transplant, the old kelp is removed and the substrate is cleaned. Usually the holdfast from the old alga can be pried off the substrate with little effort and the old bungee cords that attached the first giant kelp can be salvaged for use on the new alga. The old kelp plant is bagged so that it is easy to pull out of the tank and put aside. The substrate is scraped

clean of algae and old haptera so that the new haptera from the new *Macrocystis* plant can attach directly to the artificial rockwork.

Next, one of the divers goes to the surface to retrieve the new alga and returns to the transplant site. If it has not already been done, at this point the holdfast can be shaped with a knife to fit the transplant site. As mentioned previously, the exhibit gets a good deal of *Macrocystis* recruitment usually along the back wall closest to the wave machine. Occasionally, adult giant kelp was removed from the back wall instead of collecting it from the wild and transplanted on a reef. No subjective differences were observed between survivorship of the transplants.

Figure 5. Trimming and shaping the holdfast before transplanting in the kelp forest exhibit.

As previously mentioned, there are usually several attachment sites with screws at each transplant site. Usually the easiest installation method is to attach the holdfast between the same screws that the old alga fit between. If this works, the same bungee cords can be used. There are usually a number of attachment sites with screws so the holdfast can be moved around until it fits between two screws. If there are no existing attachment sites that are the distance apart to insert the new holdfast, a new attachment site is drilled. A pneumatic drill is kept at the surface and an extra supply of rock anchors, screws, and a hammer are brought down in a goody bag in case a new hole must be drilled.

Once two good attachment sites are found, two prepared bungee cords are placed around the first screw via the monofilament attachment on the end. These bungee cords should be long enough to reach the other attachment site but short enough to be able to stretch a little so that the bungee cords strap the holdfast down so that it is taught against the haptera. The new *Macrocysits* is placed on the substrate between the attachment sites. The first bungee is stretched around the stipes on one side of the holdfast and anchored on the opposite screw. Once the first

bungee is hooked on the screw head, the other bungee is stretched across the other side of the holdfast around the stipes. This procedure must be coordinated between the two divers. One diver usually holds down the buoyant plant and stretches the bungee across the holdfast while the other works on attaching the monofilament using one or two screwdrivers to hook the monofilament loop under the screw head. Generally, the first bungee is easy to attach and the second one is more challenging since there is already a taught monofilament loop just under the screw head. The holdfast is then checked to make sure that it is anchored securely on the substrate by the bungee cords and that it does not move easily. If the holdfast moves easily, the bungee cords are either adjusted on the holdfast or another bungee is attached through the middle part of the holdfast. Once the plant is firmly secured to the rockwork, the fronds are untangled.

Results

From September, 1994 to February, 2001 the date and position of each transplant performed in the KFE was recorded. During that time, 84 adult giant kelp were transplanted from the Monterey Bay. All sites except K1 were occupied by transplants continuously. The last sites to be transplanted were not counted because there was not a replacement date. As a result there were 74 transplants that had an insertion and replacement date. The longevity of each transplant was measured in days by taking the difference between the insertion and replacement date.

The overall mean survivorship for all transplants in the KFE was 256 days or about 8 ½ months while the median was slightly lower at 214.5 days. The average survivorship when each site was averaged was 304 days or about 10 months. The site that was transplanted most often was K10 and the average survivorship was 166 days. The longest transplant survivorship was K3 averaging 545 days. In fact, there were only three transplants on that site during the six-year period. The minimum time a transplant remained on one of the sites was eight days at K2. There were six transplants that lasted less than a month. Generally, if a transplant was replaced within a month, the kelp plant was not attached properly or a fish, typically one of the sheephead, dislodged the alga before the holdfast had time to attach itself to the substrate. The maximum longevity of a transplant was 818 days at K11 and there were three transplants that lasted more than two years. During the study period (September, 1994 to February, 2001) each site was replaced an average of 7.4 times and about 13 transplants were done per year.

Statistical analyses were performed using the software program Systat 9.0 (SPSS Inc., Chicago, IL). Data were analyzed by a one-way analysis of variance (ANOVA), with site (transplant site, reef, side of tank) or time (year, month, period) as fixed factors, and longevity as a random factor (Table 1). Whenever the fixed factor included more than two levels, the ANOVA was followed by multiple comparisons of all possible pairs of means using the Tukey procedure (Wilkinson, et al., 1996). By convention, a probability below 5% ($p<=0.05$) was regarded as significant.

Table 1. Statistical comparisons of transplant data.

Analysis	ANOVA p value	Tukey Pairwise Significant p values
By Transplant Site: K2-K11	**0.012**	K3 vs K7: 0.038 K3 vs K10: 0.032
By Reefs: K2, R2, R3, R4, R5	0.323	Not significant
By side of Exhibit: K2-K6 vs K7-K11	**0.022**	Not applicable
By Year: 1995-1999	0.218	Not significant
By Month: January-December	0.298	Not significant
By Season: Spring, Summer, Fall, Winter	0.205	Not significant
Before and After El Nino	**0.001**	Not applicable
Before, During, and After El Nino	**0.003**	Before vs During: 0.033 Before vs After: 0.003

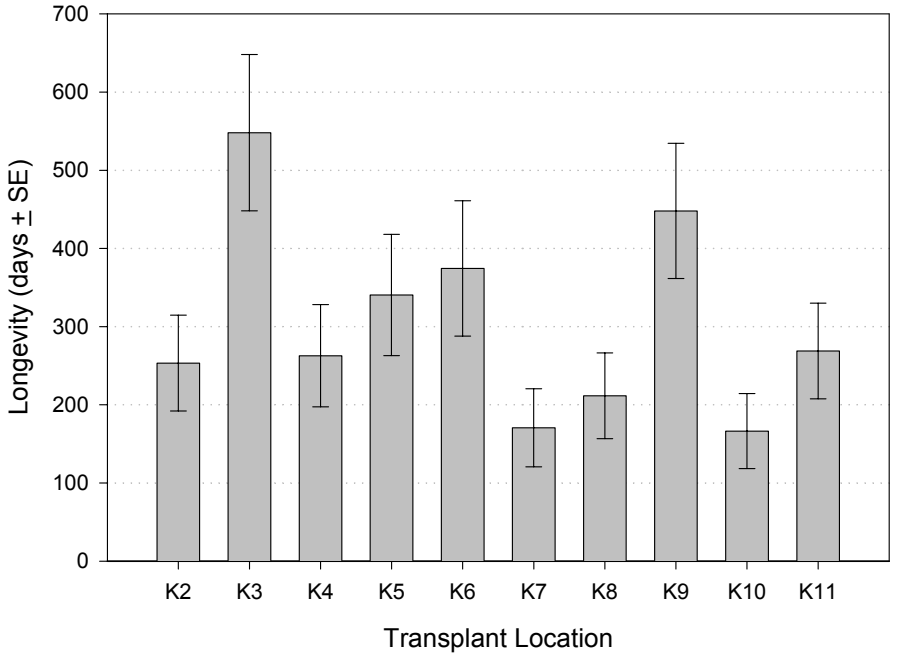

Figure 6. Average transplant longevity.

Analysis of Transplants by Position

An analysis of the transplants by position in the KFE were done to see if there would be significant differences between each transplant site, reef site, and the side of the tank that the transplants were located on. While the results were highly variable (Figure 6) the one-way analysis of all the data revealed that there were significant differences between the site locations ($p=0.012$). More specifically, the Tukey pairwise comparisons revealed survivorship at K3 was significantly longer than position K7 ($p=0.038$) and K10 ($p=0.032$). K3 had a mean of 548 days while K7 and K10 had 170.6 and 166.2 days, respectively.

It was suspected that adult giant kelp tended to do better in specific areas of the exhibit. Observations revealed that the kelp plants tended to look healthier at K2, and on reefs two and three (R2 and R3, respectively). Kelp on the reefs four and five (R4 and R5, respectively) were often observed to have fewer stipes and blades, more epiphytic growth, and generally had a more tattered appearance. Numerous *Macrocystis* recruits were often observed growing on R1 and along the backwall above R1 and R2. Furthermore, the wave machine is located above R1 (figure 3). The wave motion tends to be stronger in proximity to the wave machine and tends to peter out as the distance increases. The northwest side of the exhibit (akin to southern exposure or south facing slopes) also gets more sunlight. In fact, very little if any sunlight hits the bottom of the tank on the southeastern side around R4 and R5 during the winter. The orientation of the buidings also tends to shade the southern end. Interestingly, an analysis of variance of longevity by reefs revealed no significant differences ($p=0.323$). However, when the northwest side transplants (K2-K6) were grouped and compared to the southeast side transplant sites (K7-K8) there was a significant difference ($p=0.022$, figure 7). The northwest side had an average longevity of 322.6 days in comparison to 218.4 days at the southeast end for all transplants during the six-year time period.

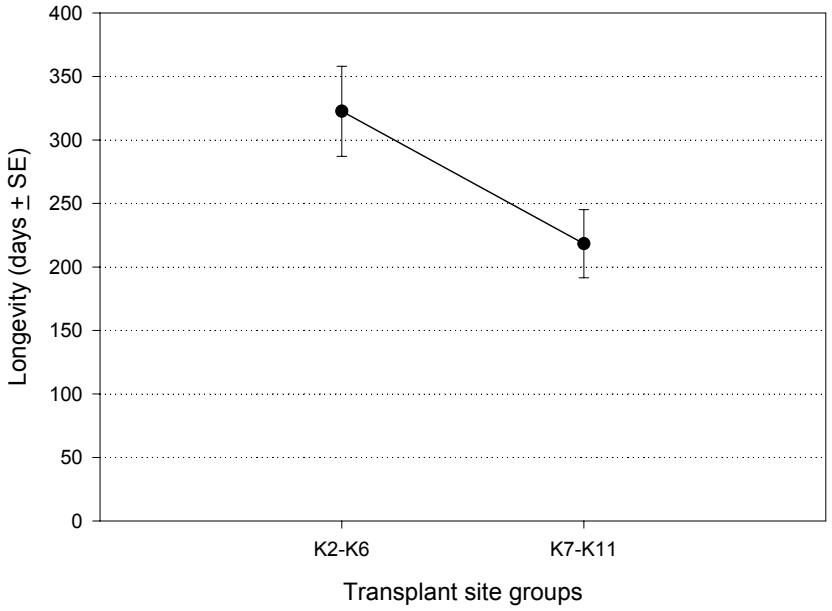

Figure 7. Average transplant longevity by side of exhibit.

Analysis of Transplants by Time

Analysis of different time periods was also done to see if there would be any significant differences. One way analysis of variance of the kelp transplants by year revealed no significant differences among years (1995 through 1999, p=0.218). Data from 1994, 2000, and 2001 were not analyzed because longevity data were incomplete. An analysis of the data by month collected revealed no significant differences either (p=0.298). The data was also analyzed by season. Although there were no significant differences (p=0.205), a pairwise comparison of summer and fall was close (p=0.058). The summer mean was 330.7 days while the fall mean was 149.1 days (Figure 8).

In addition to year, month, and season comparisons, there were three time periods that the data could be divided into.

An oceanographic anomaly referred to as the El Niño-Southern Oscillation (ENSO) occurred during the winter of 1997–98. El Niño is a large-scale oceanic warming event that affects most of the Tropical Pacific. During El Niño the trade winds weaken over the tropical Pacific, upwelling weakens, and warm water flows back east in a slow wave, accumulating along the coast of the Americas. This affects the thermocline on both sides of the Pacific and causes a change in atmospheric circulation referred to as the Southern Oscillation (www.csa.com 1998; Moran and McDonald 1995).

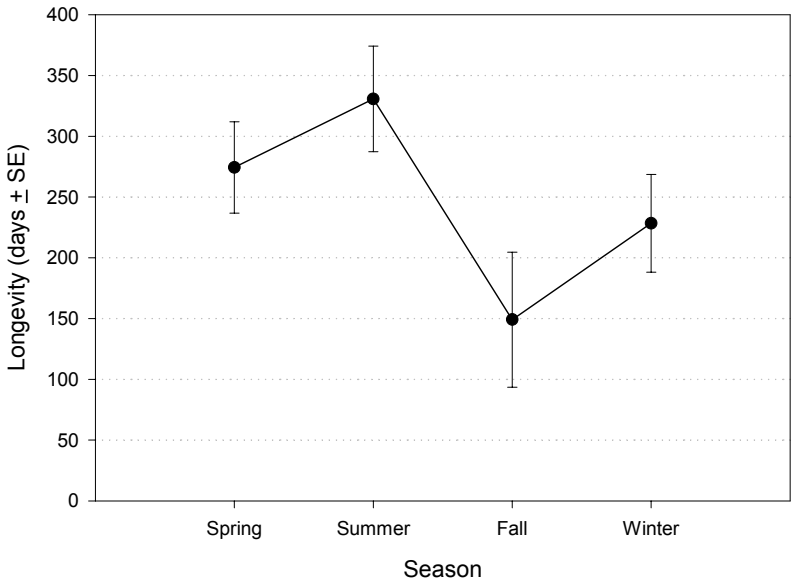

Figure 8. Average transplant longevity by season.

Beginning in late July, 1997 surface seawater temperatures in Monterey Bay began to rise above normal. During August incoming seawater temperatures exceeded 16.5^{o} C, approximately 4^{o} C above normal for this time of year. Nitrogen concentrations in incoming seawater also

declined during July. Subjective observations of the KFE during late August suggested that the health of giant kelp plants was deteriorating. Blades appeared pale and frayed, and mature blades seemed to be senescing early, resulting in fewer blades on the fronds. Giant kelp plants in the field were in a similar, poor condition with reduced biomass and a pale, tattered appearance. The elevated seawater temperatures continued through October 1998.

Another event that may have affected the longevity of the kelp transplants in the KFE is that there was a change in the *Macrocystis pyrifera* collection site. In October 1997 the Monterey Bay Aquarium voluntarily decided to stop collecting in a stretch of coastline and the subtidal waters to the 60-foot mark that ran from the Breakwater in Monterey to Lover's Point in Pacific Grove. This stretch of coastline was under consideration for a city marine reserve. While it has yet to be officially designated due to court battles it will probably be designated as part of the state-wide MLPA process and the Monterey Bay Aquarium has indefinitely abandoned that area as collecting site. Before October 1997 this area especially the kelp forest around the Breakwater was the primary site of collections. After October 1997, a new collection site was chosen that was outside the proposed reserve. Kelp was collected primarily from Otter Cove off of Pacific Grove.

A comparison of the time period before the El Niño, September, 1994 to June, 1997 and after the El Niño event: July, 1997 to February, 2001 revealed a significant difference in longevity between time periods ($p=0.001$). The data set could also be divided into three distinct time periods:

Time Period	El Niño	Collection Site
February, 1994 - June, 1997	Before El Niño	Breakwater
July, 1997 - October, 1998	During El Niño	Both sites
November, 1998 - February, 2001	After El Niño	Otter Cove

A one-way analysis also revealed a significant difference ($p=0.003$) and pairwise comparisons were significantly different between the first time period and the second time period ($p=0.033$) as well as the significantly different between the first time period and the third time period ($p=0.003$). Figure 9 shows that the mean survivorship of transplants significantly decreased by successive time periods.

Discussion

Transplant Longevity by Position

Comparison of data by transplant site is highly variable. It is difficult to piece together why one transplant site is successful and another one is not. For instance, K9 is on the same reef and is only six feet away from K10 yet each plant on K9 survived an average of 282 days longer. Biological explanations might include the fact that K10 is one of the furthest transplant sites away from the wave machine so it gets the least wave motion. It is also located on the southern side and gets less sunlight than most of the sites. K11 should also have a low survivorship for the same reasons but actually has a higher average longevity then K7, K8, or K10, which are all closer to the wave machine and get slightly more sunlight. The only physical difference between

these sights besides proximity to the wave machine and amount of sunlight is shape of the tank. Since the tank is kidney shaped, K10 is located around the corner while there are no obstructions between the wave machine and K11. The wave motion may be blocked slightly by the Window 4 (Figure 3) at K10. No chemical or physical data (e.g. light levels, nutrient levels, water motion) was measured. Without such data attempting to pinpoint the exact reasons there is spatial variability in transplant longevity can only be "handwaving" (Phillips 02).

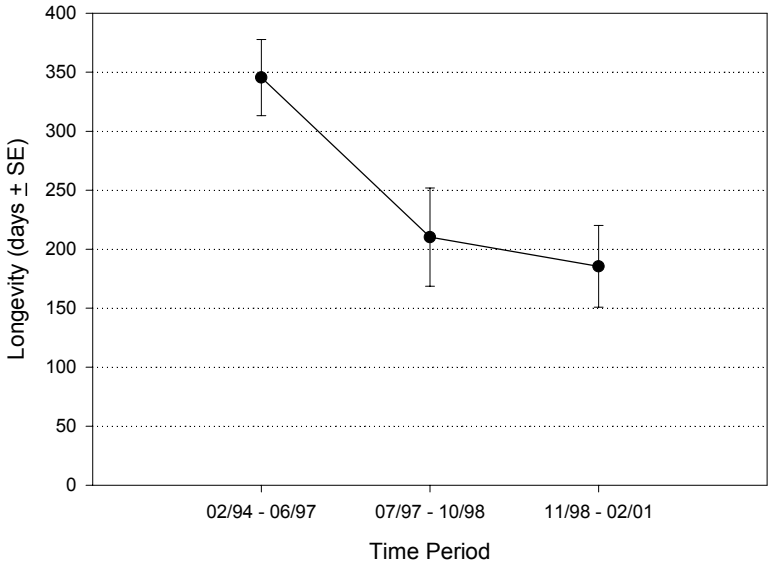

Figure 9. Average longevity by time period.

While biological reasons such as wave motion and light levels may affect transplant longevity, another possibly more compelling reason may be selective transplantation. Each site is not as visible to the visitor. For instance, K3 had the highest transplant longevity of 548 days. Physically, K3 and K2 are both in close proximity to the wave machine and get about the same light levels. However, K3 is hidden behind K4 while K2 is easily seen from the visitor perspective. Thus, K3 may not be "selected" to be transplanted as often as other transplants that are more noticeable to the visitor perspective such as K2. The main view of the KFE is located in front of reef two and three (K2-K8). In general, the transplants that were most visible to the visitor such as K2, K4, K5, K6, and K7 were assessed more critically than the other sites. Although it was preferable to have all plants at the same level of aesthetics there may have been a higher aquascaping standard for kelp transplant locations such as K2, and K4-K7. In addition, as was mentioned previously, the Northern side of the exhibit tends to have healthier looking *Macrocystis* and statistically, K2-K6 has a significantly greater longevity than K7-K11. Another outlyer is K9 which has the second greatest longevity of 448 days. Although it is on the southern end perhaps it is not transplanted as often because it is not as noticeable from the visitor perspective. It is difficult to explain the variability of the longevity of the transplant sites when there are a number of subjective decisions involved in the process.

Transplant Longevity by Timeperiod

The statistics analysis of the data implies that there is a significant difference in longevity of transplants before and after the El Niño event. The effects of El Niño on abiotic factors affecting giant kelp has been described in other literature. A strong El Niño results in elevated sea surface temperatures and a reduction of upwelling along the Pacific Coast of North America. Above average seawater temperatures can impact kelp in several ways. In areas of coastal upwelling an inverse relationship exists between seawater temperature and nitrogen availability. In southern California warm water periods or El Niño events have been shown to significantly reduce productivity in coastal giant kelp beds. The principal factor affecting kelp growth during warm water periods is nitrogen limitation. Furthermore, it has been shown that giant kelp can maintain high growth rates for only one month after the onset of extremely low nutrient availability (Zimmerman and Kremer 1986, Kopczak et al., 1991). Above-normal water temperatures can also cause thermal stress in kelp tissues and may affect metabolic processes. Kelp tissues become predisposed to invasion by gall-producing bacteria at elevated temperatures (Phillips, personal observations). So the statistical difference in transplant rates before and during El Niño is understandable given what we already know about warm water events.

However, what is more interesting is the fact that after the El Niño event was over and Monterey Bay water temperatures return to normal, the longevity of the kelp forest transplants continue to decline. The main difference between the transplants before and after the El Niño event was that the collection site was changed. This implies that the collection site may affect transplant longevity in the KFE.

When looking at the different collection sites the place that was used after El Niño (Otter Cove) is much closer to the open coast near the entrance to Monterey Bay than the site that was used before El Niño (the Breakwater). As a result the wave action tends to be stronger at Otter Cove. The wave action of the Breakwater is more akin to the KFE than Otter Cove. Giant kelp is very plastic and adapts to its environment. Open coast giant kelp blades tends to be smaller, less numerous, and in general have less surface area. This creates less drag in the wavier environment and possibly enables longer survivorship as a result. However, a plant with less surface area has a reduced ability to photosynthesize and grow. It is possible that kelp plants transplanted from an environment with stronger wave action has a lower survivorship than plants transplanted from a milder wave environment because it has fewer blades to photosynthesize and re-establish itself. Furthermore, due to the shape of the exhibit there is less sunlight that reaches each kelp plant than when each kelp plant was in the wild. Additionally, the kelp at the breakwater grow at the same depth as the depth of the KFE (15-25 feet) while the depth that the *Macrocystis* grows at Otter Cove is 30-45 feet. Perhaps the difference in depth may effect how well the transplants last in the exhibit. Examination of these abiotic factors suggests that the original site may have been better suited to giant kelp transplant collections.

The successful attachment and adaptation of giant kelp transplants to the KFE is not only variable by sites within the exhibit but also by changes in large-scale abiotic factors such as El Niño events and changes in collection sites.

Acknowledments

I would like to thank Roger Phillips for his help with statistical analysis and Systat. The help of Kris Ingram and Eric Kingsley was appreciated in preparing the figures. Finally the numerous SCUBA dives done by volunteers and aquarists over the six-year period has been invaluable in doing this study.

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A DISCUSSION OF A NUDIBRANCH SPECIMEN, *Dirona aurantia,* FOUND SOUTH OF NORMAL RANGE, WITH NOTES ON ITS OCCURRENCE, HISTORY AND BEHAVIOR IN CAPTIVITY

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Abstract: *Dirona aurantia*, family Dironidae, is a northeastern Pacific nudibranch commonly found from Port Valdez, Alaska to Seattle, Washington. Recently a *D. aurantia* specimen was observed and collected in Newport, Oregon. This particular occurrence, history of the species, and its behavior in captivity are discussed in this report.

INTRODUCTION

The nudibranch *Dirona aurantia* was originally collected in Puget Sound from Orcas Island, Blakely Island, and San Juan Island (Hurst, 1966). The southern range was extended to Alki Point, Seattle in 1971 (Robilliard, 1971), and the northern range was extended to Port Valdez, Alaska in 1974 (Robilliard and Barr, 1974). On 25 November, 2003 a live *D. aurantia* specimen was collected from a boat dock in Newport, Oregon along the Yaquina Bay. Although many types of nudibranchs are commonly observed in Yaquina Bay, this animal is unique to the area according to the reported range for *D. aurantia.*

From observations made by aquarists at the Oregon Coast Aquarium, other nudibranchs that are found on boat docks in Yaquina Bay include *Acanthodoris nanaimoensis, Archidoris odhneri, Anisodoris nobilis, and Janolus fuscus* which all have a reported range from Alaska to California (Behrens, 1991). Others that have been found that have a larger range include *Cadlina luteomarginata* found from Alaska to Mexica (Behrens, 1991), *Hermissenda crassicornis* found from Alaska to Mexico and in areas of Japan (Behrens, 1991), and *Triopha catalinae* and *Dirona albolineata* which both have a range from Alaska to California and in areas of Japan (Behrens, 1991). Two additional nudibranchs that are found in Yaquina Bay and considered to be cosmopolitan are *Aeolida papillosa*, which is reported to be found worldwide in cold and temperate seas, and *Dendronotus frondosus*, which is reported to be found in the northern hemisphere (Behrens, 1991).

D. aurantia, of the family Dironidae, is a brightly colored orange and white nudibranch. Originally described by Anne Hurst in 1966, this nudibranch's ground color varies from a pale orange color in northern specimens from Alaska (Robilliard and Barr, 1978) to a deeper reddish orange color in southern specimens from Washington (Hurst, 1966). There are small scattered white spots on the body and tapering white lines on the tips of each cerata (Hurst, 1966, Behrens, 1991). The sizes of *D. aurantia* range from 3 to 12 cm (Hurst, 1966).

COLLECTION, HUSBANDRY AND FEEDING

On 25 November, 2003 a *Dirona aurantia* specimen was collected by aquarists at the Oregon Coast Aquarium from a boat dock in Newport, Oregon on the Yaquina Bay. The nudibranch was brought to the Oregon Coast Aquarium and placed in a 20 gallon flow through temporary holding aquarium. Along with *D. aurantia,* two types of bryozoans found near the nudibranch were also collected and placed in the holding aquarium.

The bryozoan types were *Dendrobaenia lichenoides* (Kozloff, 1993) growing with a small mass of other organisms covering an unidentified sponge attached to the dock, and *Membranipora membranacea* (Kozloff, 1993) growing on a piece of kelp. The *D. aurantia* specimen was found on the

mass of small organisms including the bryozoan *D. lichenoides,* and the kelp with *M. membranacea* was close to the where the nudibranch was found. *D. aurantia* and its possible food items were transported to the Oregon Coast Aquarium in a 5 gallon bucket with 2 gallons of seawater from the bay. The bryozoans were put into the aquarium first. Then the *D. aurantia* was placed into the holding aquarium on the discoid shaped *M. membranacea* to see if the nudibranch had any interest in eating this type of bryozoan. *D. aurantia* showed no interest and quickly crawled off the *M. membranacea* and the piece of kelp onto the glass side of the aquarium. The holding aquarium contains algae, anemones, hydroids, and a variety of other small organisms including the *D. lichenoides* that were available for the nudibranch to eat. Although unsure what the nudibranch was eating, it was active and its abdomen appeared to be full. *D. aurantia* seemed to be scavenging on other organisms in the holding aquarium.

The *D. aurantia* specimen was moved into the exhibit on 3 December, 2003. The exhibit is a 55 gallon rocky shore habitat which houses a variety of other invertebrates and epifauna. The *D. lichenoides* and sponge grouping along with the *M. membranacea* were added to this collection of invertebrates on exhibit. Again, the nudibranch was placed on the *M. membranacea*. The *D. aurantia* specimen showed very little interest again and quickly crawled off the piece of kelp and onto the acrylic wall of the exhibit. Although it shows no interest in the bryozoan *M. membranacea,* the *D. aurantia* specimen is active on exhibit scavenging on other food items. Its possible it scavenges on the bryozoan it was found on, the *D*. lichenoides, or other small organisms.

Hurst stated, "*Dirona aurantia* lives well scavenging in aquaria." (1966). *D. aurantia* is reported to have a wide range of tastes including bryozoans (Hurst, 1966, Robilliard, 1977, Todd and Havenhand, 1989, Kozloff, 1993) such as *D. lichenoides* (Todd and Havenhand, 1989)*, Bugula sp.*, and *Flustrella sp.* (Robilliard, 1971). It also feeds on hydroids and vegetable matter (Hurst, 1966, Robilliard, 1971). Other food items include gammarids, caprellids (Hurst, 1966), tunicates, and polychaetes (Robilliard, 1971). According to research, about 75% of *D. aurantia*'s diet is bryozoans and many other items mentioned are the epifauna found on the bryozoans (Robilliard, 1971).

OCCURRENCE OF EGG MASSES

The *D. aurantia specimen* laid a coiled string of salmon colored eggs on 26 November, 2003, the second day it was in the holding aquarium. It also laid another pink coiled string of eggs on the back of the exhibit wall on 9 December, 2003. The appearance of *D. aurantia*'s egg mass closely resembles Hurst's description as "narrow pink egg string...laid in a loose coil."(1966). These egg masses were laid earlier than reported egg masses for this species. According to reports about *D. aurantia* egg masses, the eggs are found in the field between January and April and sometimes in May (Robilliard, 1971). In aquaria eggs have been reported to be laid between January and March (Hurst, 1966, 1967).

DISCUSSION

There was a specimen of *D. aurantia* found far south of this species' normal range. Although only one specimen was found and collected in Newport, Oregon, it is possible there may be more in the area. More research should be performed on nudibranch occurrence, range, and behavior in Yaquina Bay and other Oregon bays. In general most of the research available about nudibranchs on the northeastern Pacific coast has been based on California nudibranchs to the South and Washington, Canada, and Alaska nudibranchs to the North with exception to Goddard's research based in Cape Arago, Oregon (Goddard, 1984).

A possible explanation for the occurrance of *D. aurantia* in Yaquina Bay may be due to man's influence as suggested by Behrens (1991). Behrens states, "The prey of nudibranchs are frequently colonial organisms that foul ship bottoms. Nudibranchs (often with their food and eggs) can be transported long distances on the hulls of ships." (1991). Newport is a popular portage for boaters traveling south from Washington, Canada, or Alaska. It's possible this particular animal hitched a ride with a visiting boater. If this nudibranch did travel on the hull of a boat this dark orange specimen probably came from the southern range rather than it's northern range based on Robilliard and Barr's color and range description. "Most of these northern specimens are a pale orange color with white opaque pigment generally restricted to the tips of the cerata and only a few white patches on the dorsum. This contrasts with the rich orange color and considerable

amount of white pigment on specimens in the southern portion of the species range," according to Robilliard and Barr (1978).

D. aurantia is an ideal specimen for display in a public aquarium. It is a beautiful animal, brightly colored, can grow fairly large, and is easy to feed and maintain. This species could potentially live well on display for a lengthy time. Many nudibranchs are difficult to keep in an aquarium due their specialized feeding behavior. Nudibranchs as a group are considered to be specialist predators which normally feed on one type of prey. *D. aurantia* scavenges on a wide array of organisms making it a strong candidate for an aquarium exhibit.

Figure 1. *Dirona aurantia*

Egg masses laid by *D. Aurantia* at the Oregon Coast Aquarium were laid earlier than reported in other areas for this species. Some possible differences are temperature or salinity differences of Yaquina Bay compared to areas of its normal range. This may affect the time of year *D. aurantia* lays its eggs. Stress may be another possible reason the specimen laid its eggs since the animal was recently captured, transported, and placed in a foreign setting. Further research should be done to understand this behavior of *D. aurantia* and to be able to confirm if there are definite differences in behavior due to range difference.

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PRELIMINARY NOTES ON THE HUSBANDRY OF THE PYGMY SEAHORSE, *Hippocampus bargibanti* WHITELEY, 1970 AND ITS CORAL "HOST", *Muricella plectana*, VERRILL, 1869 AT THE WAIKIKI AQUARIUM, HONOLULU, HAWAII, USA

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The pygmy seahorse, *Hippocampus bargibanti* Whitely, 1970, is considered one of the smallest marine vertebrates in the world at a maximum size of about 1.5-2.0 cm. Given its diminutive size and striking appearance, they have long been sought after for display by public aquariums around the world. They were first discovered in 1969 by Georges Bargibant of the Noumea Aquarium in New Caledonia clinging to a newly collected gorgonian (Lourie and Randall, 2003). These seahorses are further unique in that they are only found living in close association with two species of gorgonian, *Muricella plectana* (pale grey or purple with pink or red tubercules) and *Muricella paraplectana* (yellow with orange tubercules) and perhaps *Anthogorgia* to which it is closely related (Fabricius and Alderslade, 2001; Lourie and Randall, 2003).

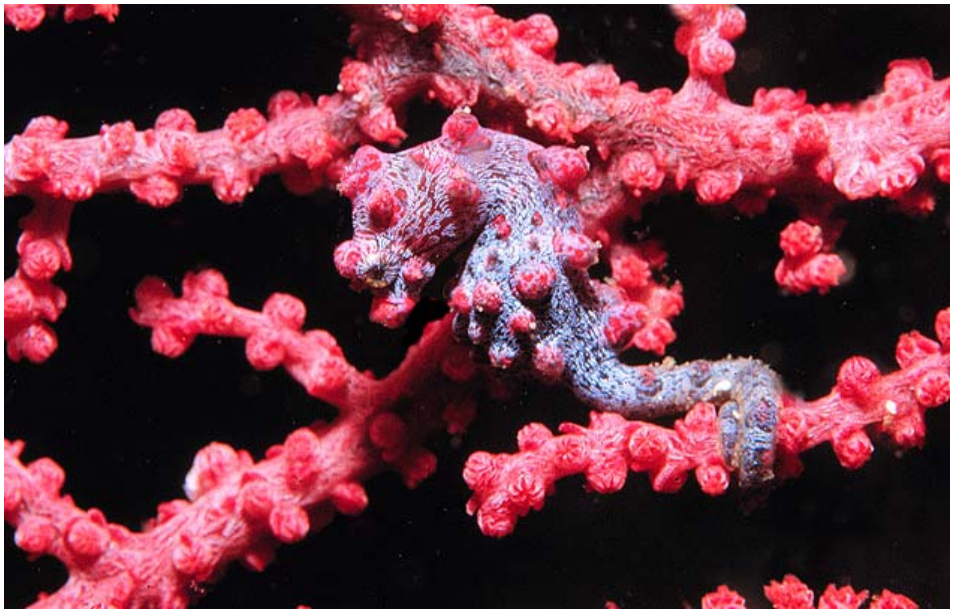

Photo 1. Pygmy seahorse, *Hippocampus bargibanti*, in situ on the gorgonian *Muricella plectana*, Lembeh Strait, Sulawesi, Indonesia. J.C. Delbeek

Muricella spp. are commonly found growing along reef slopes and drop-offs, where they encounter strong tidal currents and high particulate loads. The are found at depths exceeding 20 m (~65 ft) (Kuiter, 2001) throughout the Indo-Pacific region and southern Japan, but are not common.

In areas where cooler waters come closer to the surface, it can be found somewhat shallower e.g. Lembeh Strait, Sulawesi, Indonesia (C. Delbeek, pers. obs. 1997; Kuiter, 2001). As a result, the optimum temperatures for these corals mostly likely lie between 25 ^{o}C (78 ^{o}F) and 18 ^{o}C (65 ^{o}F), depending on geographic location and depth. Large and fan-like in appearance they can be brown, yellow, pink, orange or white with the polyp colour often strongly contrasting that of the coenenchyme (Fabricius and Alderslade, 2001).

The key to keeping *H. bargibanti* is the husbandry and survival of its host; *Muricella*. Unless one can keep *Muricella* alive, the chances of successfully keeping *H. bargibanti* is probably close to zero. The reason for this is that *H. bargibanti* relies on the polyps of *Muricella* to trap food items that it then plucks from the tentacles of the coral. This behaviour led to claims that the seahorse actually consumed the coral polyps (Kuiter, 2001) and to the unaided eye, observing underwater through a SCUBA mask, it may certainly appear to do so, but from our observations this was not the case. This differs from the newly described species *Hippocampus denise*, which is distinguished from *H. bargibanti* by being smaller, more elongate with fewer bumps and being found mostly on pink or orange *Melithea* spp. sea fans, *Annella*, *Echinogorgia* as well as *Muricella* (Louie and Randall, 2003). This species appears to pick food more from the water column or from the surface of the coral than the polyps and is more active than *H. bargibanti*, making it perhaps, a better husbandry candidate (C. Delbeek, pers. obs. 1998; Lourie and Randall, 2003). Kuiter (2003) has recently described what could be a third species of pygmy seahorse, *H. colemani* form Lord Howe Island, Australia.

Collection and Transport

While on a trip to southern Japan in September of 2003, the Waikiki Aquarium was fortunate to have the chance to acquire two pieces of *Muricella plectana* and two specimens of *H. bargibanti* from local collectors. These were collected using small collecting bottles for the seahorses, at a depth of about 50 m (~120 ft.). The seahorses were brought up slowly (several hours) from that depth by line to the collecting boat and taken back to shore. The seahorses were shipped separately from the gorgonians directly from the collection site to the exporter where one of us (JCD) took delivery when they arrived. The gorgonians were then immediately packed separately with seawater and oxygen (50:50) and each of the seahorses was placed in its own shipping bag with water and oxygen (50:50) with a volume of about 2 liters. In addition, thin PVC rod (2mm dia.) was folded into a pretzel shape and placed in each shipping bag. This provided a hitching post for the seahorses, so that they would not tire themselves by having to remain in the water column by continually swimming.

Husbandry Observations

After a return trip to Hawaii of about 12 hours (packing, holding and flight time) the gorgonians were added to a 15 gallon glass holding tank that was plumbed as an open system. An airstone was used for circulation and the water temperature was 78 ^{o}F. The seahorses arrived in good condition, were added to the gorgonians, and immediately reattached themselves. The polyps of the gorgonian began to extend themselves in a few hours and all appeared well.

For the next three days, the gorgonians were observed to release eggs each day for about an hour. At first, this created some excitement but then it soon became apparent that this was

most likely a response to stress, possibly shipping but more likely the warmer water temperature. The seahorses were seen to move from branch to branch and orient themselves in a variety of positions as they carefully searched every square millimeter of the corals surface.

Photo 2. *Hippocampus bargibanti* at the Waikiki Aquarium exhibiting its typical behaviour … searching the gorgonian, *Muricella plectana*, for food. N. Chan

We fed a variety of foods to the system. Live *Artemia* nauplii, live *Euterpina acutifrons*, copepods (adults and naupilli), live rotifers *Branchionus plicatilis*, frozen Cyclop-eeze copepods and live phytoplankton (*Chaetoceros gracilis* and *Tetraselmis chuii*). We also made a "mash" consisting of clams, shrimp, fish, phytoplankton and powdered *Spirulina* algae. Feedings were done every other day with one, some, or all of the food items. Despite these foods, the *Muricella* slowly began to loose tissue. By early December, fully 90% of the tissue had been lost. However, during this time, the seahorses appeared to be doing well. Due to the small size of the fish and the food items used, it was difficult to directly observe any feeding. However, using a hand magnifying glass they were observed to consume *Artemia* that had been trapped by the tentacles of the polyps (N. Chan, pers. obs.). We assume they also consumed the copepods and rotifers in a similar manner but we could not verify this. On December, 10th, we found the smaller of the two seahorses dead. At the time of this writing (December, 17th, 2003), the second seahorse is still alive.

We hope to receive a few more pieces of *Muricella* in the new year and plan to construct a better holding system for the corals. This will again consist of an open system but a sump will be constructed to allow a chiller to be installed. Several powerheads will also be used to create stronger flows that can be alternated via timers. We hope that this will allow us to address two of the major factors that were not handled well by the current system namely water temperature and water motion.

As was mentioned previously, we believe the key to keeping *H. bargibanti* is the successful husbandry of its host coral, *Muricella*. We hope that we will have better success with the next *Muricella* specimens before we attempt to obtain any more pygmy seahorses. Therefore, our advice to any institution that is interested in obtaining these unique seahorses is to first ensure that you can keep *Muricella* alive, without tissue loss, for several months before even entertaining the notion of obtaining these unique and uncommon seahorses.

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Online Information Sources

Australian Government Department of the Environment and Heritage Home Page
http://www.deh.gov.au/coasts/species/marine-fish/syngnathidae9.html

Fishbase
http://www.fishbase.org/Summary/SpeciesSummary.cfm?ID=53790&genusname=Hippocampus&speciesname=bargibanti

National Geographic
http://news.nationalgeographic.com/news/2003/07/0731_030731_seahorse.html#main

RAW 2003 ABSTRACTS
Regional Aquatics Workshop, June 5-7
Riverbanks Zoological Park and Botanical Gardens, Columbia, SC

Compiled by: James D. Clark, Aquarist
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[Editors note: Abstracts were not submitted for all papers presented. However the titles, presenters, and email addresses (where available) are provided for all papers.]

Thursday, June 5

An Update on the Zoological Management Systems (ZIMS) and How it Will Help Us All

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What in the World is Jenkinson's Aquarium?

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Recovery of Fiji Coral Reefs Following a Catastrophic Bleaching Event in 2000

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During March – May 2000, coral reefs around the Fiji Islands were exposed to elevated seawater temperatures for prolonged periods of time. During this period, we set up 11 permanent transects on inshore and offshore reefs and documented the effects on the corals. At the RAW 2000 conference, a video program and data were presented showing that a high percentage of the corals on inshore and offshore reefs were severely bleached during this high temperature event. During May 2001, we resurveyed these transects and recorded mortality of acroporid corals as high as 99% on many of the reefs. In March 2003, the transects were once again resurveyed. In general, based on the number of new acroporid colonies counted on each transect, the inshore reefs in turbid lagoon environments are showing signs of rapid recovery, while offshore reefs in a more pristine environment are recovering much more slowly.

Dallas Aquarium at Fair Park: Updates and Plans

Brian Potvin, Dallas Aquarium at Fair Park
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Conservation, Education and Science….and a New Aquarium

Dr. Heather Hall, Zoological Society of London and Joe Wetzel, Joseph A. Wetzel, Inc
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The Zoological Society of London opened London Zoo, the world's first scientific zoo, in 1828 and Whipsnade Wild Animal Park, the world's first open zoological park in 1931. In 2006, ZSL will open a third major animal attraction in the form of a world-class conservation-led public aquarium in London's Royal Docks.

ZSL's new aquarium will be the first built on the principles of conservation and sustainability, and will strive to become a world leader in aquatic research and conservation. The goal is to provide visitors with access to the beauty and wonder of life underwater so that more people will be inspired to care about the aquatic environment in Britain and the rest of the world. The Aquarium will complement ZSL's existing living collections, research and field conservation work through breeding, management, field projects, exhibits and education programmes.

This presentation will explore the challenges of developing a conservation aquarium, including exhibits, stock acquisition and interpretation, while providing an entertaining and enjoyable visitor experience.

Riverbanks' Aquarium: Where We Have Been and Where We are Going

Melissa R.H. Salmon, Riverbanks Zoological Park
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Update on the Lake Barombi Project

Colin Grist, New England Aquarium
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Atlantis Marine World: From Sketches to Fishes

Joe Yaiullo, Atlantis Marine World
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Friday, June 6

Dolphinfish in the Aquarium: From Collecting to Exhibition

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During the winter of 2002 the South Carolina Aquarium started working on diversifying the selection of pelagic species in our Great Ocean Tank, a 335,000 gallon exhibit. The species we decided to try first was *Coryphaena hippurus* (aka. dolphin, mahi, or dorado) due to it's availability offshore and proven success in a handful of other aquariums and aquaculture

facilities. One of our first challenges was how to transport a specimen from as far offshore as 60 miles. Once back at the SCA the next challenge was acclimating them to a holding tank where jumping and perimeter swimming were a constant. Quarantining was also problematic as skin abrasions and external parasites were present from day one. By the end of the summer the SCA successfully introduced four *C. hippurus* into our primary mixed species exhibit but not without more hard learned lessons. The summer of 2002 was a successful and informative year for us. Our goal for the upcoming collecting season is to continue showcasing *C. hippurus* and expanding our efforts to include other pelagic species.

Captive Propagation of the Rio Grande Silvery Minnow

Terina Niskanen, Albuquerque Biological Park

Three years ago, the City of Albuquerque and the U.S. Fish and Wildlife Service began a cooperative effort to propagate the federally endangered Rio Grande silvery minnow, *Hybognathus amarus*. The propagation effort is part of an overall conservation strategy, as outlined in the Species Recovery Plan, aimed at increasing the number of individual fish, rearing and holding captive populations and reintroducing fish into the Rio Grande. Personnel from the U.S. Fish and Wildlife Service (U.S.FWS) and the Albuquerque Biological Park (Biopark) collect adult minnows and eggs from the river and transfer them to the Biopark where they serve as broodstock for future captive populations and restocking efforts. As of this writing, the Biopark has distributed approximately 650,077 eggs, larvae and or fish to hatcheries for release, rearing and broodstock and has released 5482 to the river. Due to the success of this program, the New Mexico Interstate Stream Commission entered into a Joint Powers Agreement with the City of Albuquerque to provide $1.3 million to build a Naturalized Refugium on Biopark property to be operated by Biopark staff. The Refugium includes both indoor and outdoor facilities. The outdoor portion consists of a 50,000 gallon donut-shaped pond varying in depth from 1-60 cm. Pumps control current velocity to mimic the natural flows of the Rio Grande. The substrate is sand, gravel and silt and there are boulders and cottonwood boughs to create natural cover and eddies. There is also a 3000sq. ft building containing aquariums and pools designed as emergency holding, research space, spawning and grow-out.

Coral Spawning at Birch Aquarium: Observations on Timing and Behavior

Fernando Nosratpour, Birch Aquarium at Scripps
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The spawning of an *Acropora valida* colony, at the Birch Aquarium at Scripps, on July 5, 1999 was observed and caught on video. Sperm-egg bundles were first released by polyps located on lower/older branches and ended with higher most branches. Polyps at branch tips also spawned. In the following three years, records were maintained of the spawning times of this specimen as well as another *Acropora* colony, occupying the same tank. Most spawns of both *Acropora* colonies were inferred by the appearance of eggs in filter socks and by the absence of ovaries in polyp dissections. Both colonies shifted their spawning period by up to 6 months compared to *Acropora* species in the south Pacific, where the two originate. The *Acropora*

valida's spawns matched spawning periods of conspecifics located in reefs in the Northern hemisphere. The two species reacted differently to the artificial cues provided. There were no synchronous spawns and *Acropora valida* always spawned one to three months earlier than the other unidentified, species. Attempts at self-fertilization experiments with *A.valida* gametes were unsuccessful. Juvenile colonies, of either species, have no t been observed in the exhibit tank.

Uronemiasis in Riverbanks Zoological Park Fishes

Dr. Elizabeth W. Howerth, DVM, PhD, University of Georgia
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Uronema: Observations on an Invader

Jolene Cully, RVT, Newport Aquarium
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The purpose of this discussion will be to inform the audience on ways to prevent and contain the spread of *Uronema marinum* within marine systems. General appearance and behavior of the parasite will be addressed along with containment and quarantine procedures tested and applied by the Newport Aquarium veterinary staff.

Initial Propagation Attempts of Captive Giant Seabass

Erik Forsman, Aquarium of the Pacific
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Since its opening in June 1998, the Aquarium of the Pacific, Long Beach, California, has housed a male/female pair of giant seabass (*Stereolepis gigas*). Spawning events of this pair had been witnessed multiple times each year, however, all rearing efforts had very limited success. In November 2002 Aquarium staff again witnessed a spawning event and was given the opportunity to again make an attempt at rearing this species. Fry from this most recent trial lived up to 43 days post-hatch. Though this latest attempt was ultimately unsuccessful, a great deal was learned about the needs of this species early life history stages. Husbandry of adults, spawning behavior, and larval rearing of this species will be discussed.

Ratfish 101: The Mythical Chimaera

Helen Tozer, Living Elements Limited
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What looks like it's been created by Frankenstein, sports velcro organs and is rarely displayed in public aquariums? Why ratfish of course. Natural History and the pitfalls to avoid when keeping the spotted ratfish (*Hydrolagus colliei*), an interesting and under-utilised display species.

Case Studies of Elasmobranch Husbandry

João Falcato, Oceanário de Lisboa II
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During 2002 Oceanario de Lisboa introduced two large *Mobula mobular*, one large *Manta birostris* and two small *Prionace glauca* in its Open Ocean 5.000 m^3 exhibit. Notes on the husbandry challenges created by the introduction of such unusual species are given, with regards to feeding and general behaviour.

Gastric Torsion in a Sandtiger Shark

Cathy Zoller, Aquarium at Moody Gardens
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A male Sandtiger shark became weak and unresponsive immediately following transport. The animal was treated with steroids, antibiotics, and sodium bicarbonate but later died and upon necropsy was found to have a gastric torsion. Sections of various tissues were examined histologically for diagnostic evaluation. Post mortem findings in the brain, liver, and intestinal vasculature are suggestive of an acute to subacute bacterial septicemia, which may have occurred secondary to the gastric torsion and severe bleeding into the gut

Breeding and Raising the Oceanic Seahorse

Jeffrey S. Mitchell, Shedd Aquarium
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The seahorse, *Hippocampus sp.*, is highly regarded as a popular aquarium display animal as well as an important economic resource for many individuals worldwide. Attempts to keep these fish in aquaria have met with limited success until recently. More and more, seahorses are becoming a popular display animal for public aquaria. Their value as a flagship species for promoting conservation is almost unrivaled in the marine community.
Because of these issues, Project Seahorse and the Shedd Aquarium have teamed up to help promote global conservation. Working with governments, fishers, collectors, traditional medicine practitioners, and others to promote the sustained use of seahorses has been a large goal of this project. Another main goal is to develop and learn more about the natural history and husbandry of seahorses.

The oceanic seahorse, *Hippocampus kuda*, was studied with an emphasis on breeding and raising the seahorses. There are special techniques for encouraging breeding of the adults along with raising the juvenile seahorses. Techniques that have proven successful include the use of vitamin and fatty acid enrichments, in-house cultured live foods and properly sized frozen foods. Live foods that are used include copepods, juvenile and adult mysid shrimp, rotifers, *Artemia* nauplii and adult *Artemia*. Another technique that seems to increases survival rate is using air stones instead of filters for the first three weeks.

The oceanic seahorse gave birth every 14 days during the breeding season that lasted 9 months. Between 978 and 1,482 juvenile were born each time with a mean of 1,222.12. The

newborn seahorses measured a minimum of 6.23 mm and a maximum of 8.54 mm with a mean of 7.4549 mm. They weighed between 0.0015 to 0.0038 grams with a mean of 0.002448 grams. They were measured regularly for the first 31 days. On day 31, the measurements were from 16.76 mm to 26.37 mm with a mean of 22.6653.

Giving the proper food items to juvenile seahorses at specific times in their juvenile growth stages is a critical requirement for survival. The trail and error methods that are currently being used have proven successful for the first 90 days of life.

WOW, That's Going to Leave a Mark!

Jennifer Yost, Virginia Marine Science Museum
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Seahorses are difficult to tag and identify. Many different methods have been used over time. Our work utilizes the ancient art of tattoo blended with the morphology of *H. erectus* to create a unique method of identification. This presentation will describe preliminary investigations into the use of tattooing as a viable means of sea horse identification.

Reproductive Husbandry of Weedy Seadragons

Shelly Scott, Tennessee Aquarium
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In 2001 and 2002, the Tennessee Aquarium husbandry staff faced challenges propagating weedy seadragons *(Phyllopteryx taeniolatus)*. The husbandry techniques used each year to raise the weedy seadragons were examined and compared. In both year classes, the gravid male weedy seadragon was housed in a holding cage contained inside the existing tank. In 2001, the cage proved difficult to clean, stressful to the male, and resulted in disease issues and premature births. The 2002 year class had higher hatch ratios and fewer disease issues, due in part to the use of preventive medications. However, at approximately 20 weeks of age a majority of the seadragons were observed to have underdeveloped swimbladders. We suspect that air ingestion shortly after hatching may be necessary and that methods used to transfer fry are integral to proper development of seadragon swimbladders. New and improved techniques are proposed for future successful egg transfers in efforts to increase the survival rate and long-term health of the juvenile weedy seadragon.

Saturday, June 7

Clarifying Water Quality: A Review of Terminology and Testing Methods

Dave Cohrs, National Aquarium In Baltimore
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Determination of Praziquantel in Seawater by High Performance Liquid Chromotagraphy

Thoram Charanda, Living Seas Aquarium
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Amazon Life Support Systems: Mimicking Nature

Andy Aiken, National Aquarium In Baltimore
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Life Support Project Study: Manatee Coast at Columbus Zoo

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Advances in Tank Design for Portuguese Man-O-War

Justin Pierce, Audubon Aquarium of the Americas
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This presentation is a follow-up from the original one at RAW 2001 Denver CO. It explains functional advances in design of exhibitry for the Portuguese Man-of-War. The prototype tank (discussed RAW 2001) functions by drawing water down through acrylic tubes, which hold the floating Man-of-War in the center. Unfortunately, they are seasonal animals and problems arise when there are no specimens to exhibit. With the previous design, the tank is useless for housing any other animal. The solution is to make the exhibit transformable into a standard-type jellyfish (or other) aquarium when Man-of-War are not available. A new holding system for experimental husbandry will also be discussed.

Benefits of Continuous Unattended Water Quality Monitoring

Cameo Heiss, Newport Aquarium
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Through the use of theYSI 5200, a recirculatory system monitor, on a 5500 gallon live coral reef tank, the staff at The Newport Aquarium has been able to closely monitor the system. After trending the system for over a year, we have come to realize the benefits and capabilities of these control devices.

Sometimes It's Good to Be A Little Square

Jeffrey Landesman, Cabrillo Marine Aquarium
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Creating a Changing Exhibit without Changing Exhibit Space

Pam Lyons, Newport Aquarium
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As is the case with most new aquariums, Newport aquarium experienced a gradual drop in attendance after its initial grand opening in 1999. Though the attendance trend was not unexpected, it was critical to boost sales in 2003 to financially prepare for the first phase of the aquarium's expansion that will open in the summer of 2004. Situated in the greater Cincinnati area, Newport aquarium relies more heavily on repeat attendance from the local region as compared to tourism. Traditionally, public aquariums have been successful driving repeat attendance by incorporating a changing exhibits program into their operation. A designated changing exhibit space is usually essential to achieve the desired impact from a new exhibit. Unfortunately the changing exhibit space that was originally planned for Newport aquarium was delayed until the 2004 expansion. The exhibit team was challenged by needing to create a high profile, changing exhibit in the existing building layout. The decision was made to thread the exhibit within the aquarium's existing visitor path. In order for the concept of the "threaded" exhibit to be effective, a strong central idea with an equally sound conservation message had to connect all the components. A clear and visible introduction of the exhibit premise was critical so visitors would understand the concept of the interwoven exhibit and would know how to locate exhibit elements. For repeat visitors to feel they experienced something new, the exhibit elements had to be prominent while complementing the aesthetics and themeing of existing galleries. The result of the team's efforts was "turtles: journey of survival". 23 species of turtles are featured in this new exhibit that combines simple visual elements with the latest technology to tell the story of this amazing group of animals, why they have managed to survive the past 200 million years only to face a precarious future.

Butterflies of the Sea: Chilly but Charming

Helen Tozer, Living Elements Limited
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Clione limacina have been a huge hit in Japanese aquariums for many years. The Japanese even have a dark superhero called "Clione Man". This talk will discuss the natural history and captive husbandry of these small but fascinating creatures

Phoenix Islands Cruise 2002: Paradise Violated?!

Steve Bailey, New England Aquarium
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Mudflat Metropolis

Darryl Deleske, Cabrillo Marine Aquarium
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Aquariums and the Problem of Aquatic Nuisance Species

Pete Mohan, RAW Advisory Committee Chairman
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As custodians of large collections of non-native aquatic species, public aquariums are uniquely qualified to educate the public about ANS issues. Unfortunately they are also possible entry points for some of these exotics into native ecosystems. Careful evaluations of waste systems, site drainage, transport methods, acquisition and deaccession protocols, and plans for dealing with natural disasters should be integral parts of collection planning. Differences in each facility's proximity to natural waterways, local climate, and collection will require the creation of site-specific ANS containment strategies.

Shedd Aquarium's Freshwater Stingray Program

Erica Clayton, John G Shedd Aquarium
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I would like to talk about the Shedd Aquarium's Freshwater Stingray Program. I will touch on some of the taxonomic challenges in working with the family *Potamotrygonidae*, the species that we have decided to work with, a birth that we had of 'Starburst Ray', and some of the things we have learned about the 2 less commonly worked with Genus- *Paratrygon* and *Plesiotrygon*. If possible, I would then like to lead a discussion about this family, and talk about the possibility of forming a interest group with that can focus on this species.

USING GARLIC AS AN APPETITE STIMULANT IN SAND TIGER SHARKS (*Carcharias taurus*)

Denise Ashdown, Senior Aquarist and Gary Violetta, Curator of Fishes
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SeaWorld Adventure Park, Orlando, Florida

Abstract:

For many years, fish keepers have been using supplemental garlic in their fish food for parasitic control and more recently as an appetite stimulant. This study was conducted to observe if supplemental garlic would increase food intake in two anorectic sand tiger sharks (*Carcharias taurus*).

Introduction:

Throughout the centuries, garlic seedpods, *Allium sativum,* have been said to be an effective parasitic control and an old Chinese goldfish remedy (Herwig, 1979). Allicin a.k.a. Diallyl thiosulfinate (*Allium sativum*) is the active pharmaceutical ingredient in garlic. Allicin has anti-bacterial, anti-viral, and anti-fungal properties and controls pathogenic protozoans such as *Cryptocaryon irritans* in saltwater fishes (Cortes-Jorge Jr., 2000), protozoans in freshwater fishes (Bauer, 1958) and internal nematodes (Bartelme, 2003). Garlic also appears to be an appetite stimulant when added to foods (Bartelme, 2003). There are various new food products containing garlic available to aquarists. Garlic Xtreme™, which is 99% *Allium sativum*, is advertised as "a natural attractant for fish and will help cause finicky eaters to take food" (Kent Marine Inc., 2001). Garlic flavor is also being used in sport fishing to attract game fish (Robbins, 2001).

Background information:

The shark exhibit at SeaWorld Adventure Park Orlando is a 660,000 gallon oblong aquarium. The water temperature is kept between 25 and 27 degrees Celsius and the salinity is 30 parts per thousand. The lighting cycle fluctuates with park hours, but the lights are generally left on for about 15 hours per day. The exhibit is home to 50 elasmobranchs, including 19 sand tiger sharks, *C. taurus*. The animals are tong fed twice a week and all feeding data is recorded.

Reviewing the feeding records revealed that two sand tiger sharks, *C. taurus*, were below their weekly targeted food amount. Results from the annual shark physicals confirmed that each shark had lost weight. Because of their low captive-to-wild weight ratio percentage, these animals were chosen for the study. The wild weight was calculated based on the formula:

$$Wt = 2.594\ (10^{-6}) * TL^{\ 3.168}$$

where Wt is the shark's body weight in kg and TL is the total length in cm (Mohan, 2000). Each shark's actual weight was divided by the calculated wild weight to determine the captive-to-wild weight percentage. Sand tiger sharks with captive-to-wild weight percentages between 95% and 120% were considered within the acceptable weight range.

The largest weight for sand tiger A was 108 kg in 1990. Although there were periods of weight gain since 1990, the shark's weight had slowly declined, especially in the last three years. Between March 3, 2002 and April 4, 2003, sand tiger A lost 14 kg. At the start of this study, the shark weighed 73 kg and had a captive-to-wild weight percentage of 80%.

The largest weight for sand tiger B was 74.5 kg in March 2002 with an approximate captive-to-wild weight percentage of 90%. One year later, the shark's weight decreased to 70.6kg with a captive-to-wild weight percentage of 85%.

Procedure:

The study was conducted in the late spring/early summer and the weekly feeding data from January to March 2003 (pre-study) was compared to the weekly feeding data during the study (April to July 2003).

The targeted food amount for these two sharks is 4% of their body weight per week. For sand tiger A, the amount is 3.2 pounds per feeding and, for sand tiger B, 3.1 pounds per feeding.

Prior to feeding, approximately 1 cc of minced garlic (Spice World Minced Garlic; Spice World, Inc. Orlando, FL 32809 and McCormick California Style Minced Garlic; McCormick & Co., Inc Hunt Valley, MD 21031-1100) per pound of food was injected to the prepared whole fish food. The prepared fish food included salmon (*Salmo salar*), bonita (*Katsuwonus pelamis*), herring *(Clupea sp*.) and Pacific mackerel (*Scomber japonicus*). The prepared food was supplemented with Mazuri™ vitamins (Type: Maz Vit-Zu Sharks/Rays II; Product # 0053454; Address: 1050 Progress Drive, Richmond, IN 47374) then fed to the two sand tigers on the normal feeding schedule. During the study, behavioral observations of the sharks feeding as well as the amounts fed were recorded. This protocol was followed for 13 weeks.

Results:

Sand tiger A began eating on day one of the study almost immediately as the food entered the water. After consuming the food with minced garlic, the shark continued to eat during the entire feeding. Throughout the entire study period, sand tiger A continued to eat near or above its targeted food amount. It refused to eat only once on the day it was weighed, which was almost two months into the study period.

Sand tiger B declined to eat any food during the first month of the study and never consistently ate its targeted food amount. When the shark did eat, it would consume the garlic-injected food and return for more. Because of sand tiger B's continued inappetence, approximately two months into the study, the animal was given an oral steroid (Prednisone, 2.3mg/kg) as an appetite stimulant. The steroid did not appear to affect its feeding behavior. Although minced garlic continued to be injected into the food, the shark's appetite remained sporadic.

Tables: Sand tiger food consumption. Jan-March = before garlic was introduced (pre-study). April-July = the study period.

Total amounts of food consumed

Sand tiger	Target amt. for 13 weeks	Jan-March total	April-July total
A	83.2 lbs	46.5 lbs	75.9 lbs
B	80.6 lbs	43.9 lbs	31.6 lbs

Average amount of food consumed per feeding

Sand tiger	Target amt. per feed (4%)	Jan-March avg. amt.	April-July avg. amt.
A	3.2 lbs/feed	1.8 lbs/feed	3.0 lbs/feed
B	3.1 lbs/feed	1.7 lbs/feed	1.3 lbs/feed

* Sand tiger B did not eat during the first 5 feedings of the study.

Average amount consumed excluding fasting days

Sand tiger	Jan-March avg. amt	April-July avg. amt.
A	2.4 lbs/feed	3.0 lbs/feed
B	2.1 lbs/feed	2.4 lbs/feed

Conclusion:

During this 13-week study period, Sand tiger A increased the frequency of feeding days and increased the amount of food per feeding when offered garlic-injected food. Sand tiger B also increased the amount of food consumed on certain individual days but overall decreased its food intake. Since the cessation of the garlic additions, Sand tiger A has continued to consume its targeted food amount during most weeks. Sand tiger B has continued to eat sporadically.

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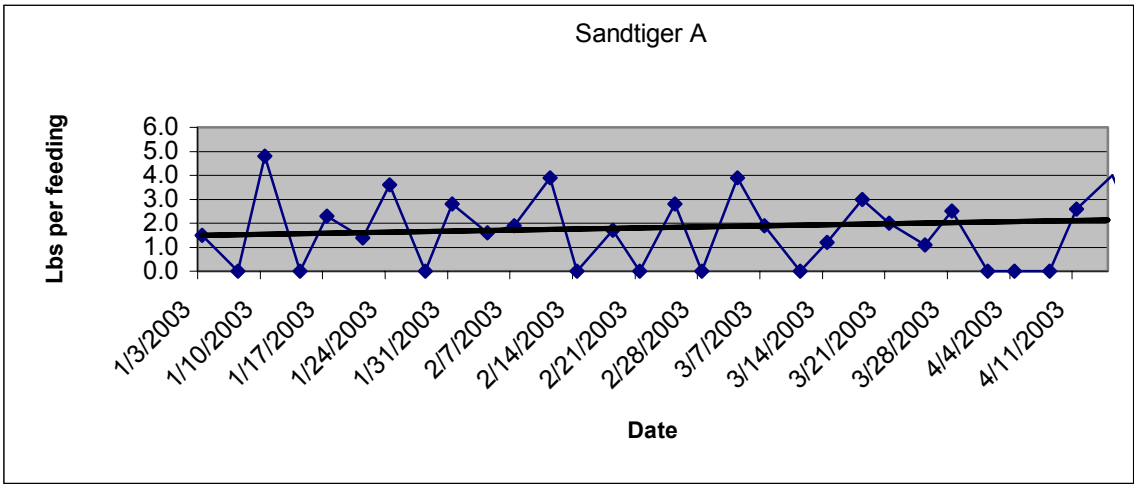
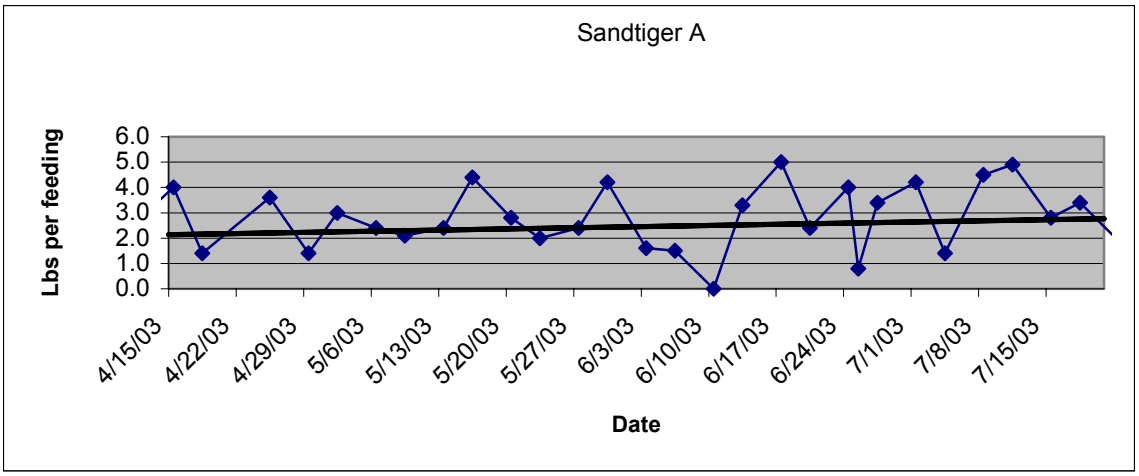
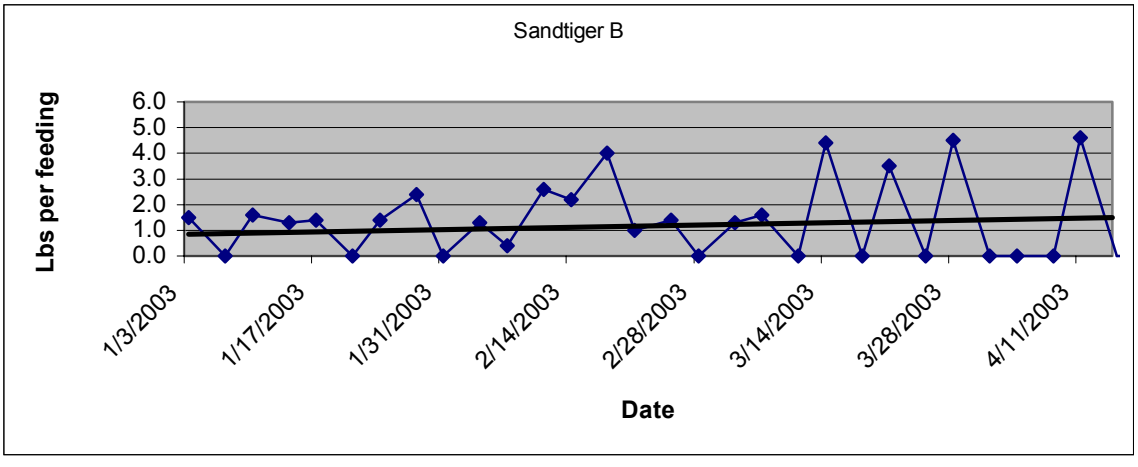
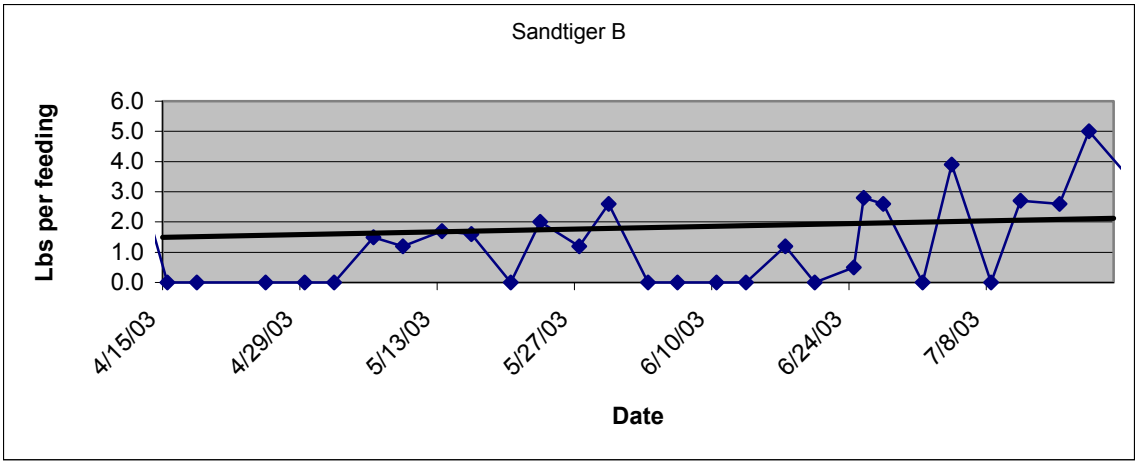
Figures: Daily feeding data for each sand tiger shark before and during the study period. The study period was from 4/15/03-7/18/03 (second graph of each set).









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