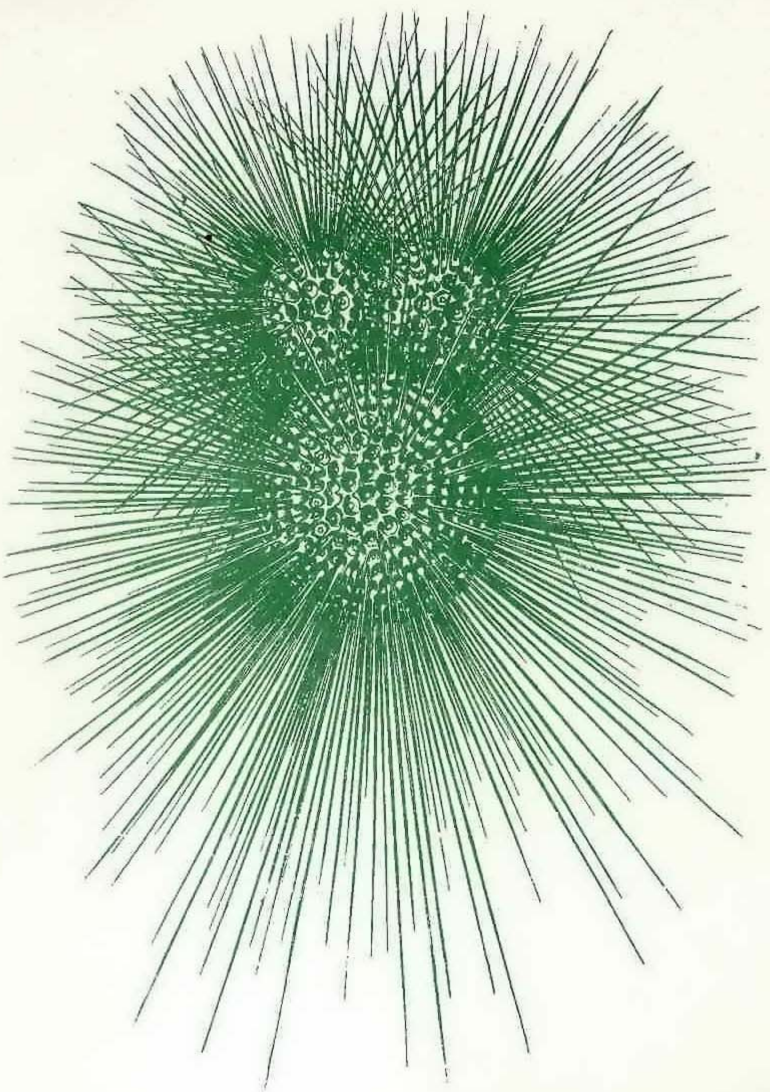
DRUM and CROAKER

A Highly Irregular Journal for the Public Aquarist

Volume 26 Feb. 1995



A BRIEF GUIDE TO AUTHORS:

1. As always, Drum & Croaker contributions are not peer reviewed and will not be edited.

2. Send typed manuscripts directly to Pete Mohan (address below). Where possible, all contributions should be submitted in letter quality Times 12pt (the type style I've used for the articles in this issue). If this is not available, please send your document in disk form to the individuals listed below. Please use the tab and center function in your software to perform these functions.

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   Text: single spacing with 1" margins. Please indent 5 spaces at the beginning of each paragraph and double space between paragraphs.
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4. "Ichthyological notes" (short contributions) are any articles, observations, or point of interest that are around one page or less in length. A brief bold faced and capitalized title should be centered, text should be single spaced, and author and affiliation should be placed at the end of the piece with the left end of each line at the center of the page.

5. Reviews of books or scientific articles are welcome, as are bibliographies. Napkin drawings will be printed "as is" - no crayon please.

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ACKNOWLEDGEMENTS

Aniko Allen typed and helped assemble much of this volume. Diane Gregg created the cover design. Bruce Axelrod and the staff of Sea World of Ohio's print shop produced this issue.

"NOT RESPONSIBLE"

The contents of manuscripts submitted to Drum and Croaker are not edited before printing. However, articles may be retyped as needed to accommodate a standard format and figures may be reduced to conserve paper.

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DRUM AND CROAKER 35 YEARS AGO

by Richard M. Segedi

From the January 1959 issue: Earl S. Herald, Editor

Caracas, Venezuela

Chris Coates advises us that the plans for the new aquarium in Caracas have gone down the drainpipe. Perhaps this is just as well since the plans included some innovations to which the fish would object.

Noumea, New Caledonia

Present emphasis at Dr. Catala's aquarium is upon anemones and other invertebrates brought up by skin divers from depths of 100 to 200 feet. Some of these are phosphorescent and under black light and make a spectacular display.

Marineland Florida

The first pigmy sperm whale in captivity started its sojourn at Marineland September 2nd. Forced [sic] feed schedule of herring kept Curator Wood in the tank a good part of the time -- what I mean is that Curator Wood feeds normally -- it's the whale that requires the force feeding.

Cleveland Ohio

Before the Bloomington meetings a group of itinerant aquarists descended upon the Cleveland Aquarium and there discovered why other aquaria have had difficulty in obtaining rare African and South American fresh water fishes. Cleveland has most of them! Despite an unimposing exterior to the building, the Cleveland Aquarium contains many ingenious display techniques which are entirely original. Kudos to Director Kelley and his staff.

Dallas, Texas

The Dallas Aquarium, located in Fair Park Civic Center, celebrated its 22nd birthday June 6, 1958. Built as part of the Texas Centennial Celebration of 1936, the Aquarium has four 1000-gallon tanks, nine of 2000 gallons, four of 3000 gallons and one 1500 gallon tank. The tropical tanks consist of two of 75 gallons, four of 50 gallons, 12 of 30 gallons, 4 of 17 gallons and 16 of 8 gallons. Open every day of the year except Christmas, and admission is free. Jeff W. Moore is the superintendent; address: 96-3 Rustic Circle, Dallas 18, Texas. Their most recent attraction is an arapaima of about 12 inches [INCHES?? RMS] length.

Vancouver, British Columbia

Newest item here is an 80-page guide book containing over 100 illustrations of aquatic plants and animals, including local and exotic forms. Curator Murray Newman is the author. It sells for $0.75. [I wonder whether or not it was in color? RMS]

New York Aguarium

Sadness reigns - the beluga or white whale obtained from Alaska died of gastritis. Olaf, the walrus, continues to be the star attraction. During the winter season the Aquarium will be open for five days of each week.

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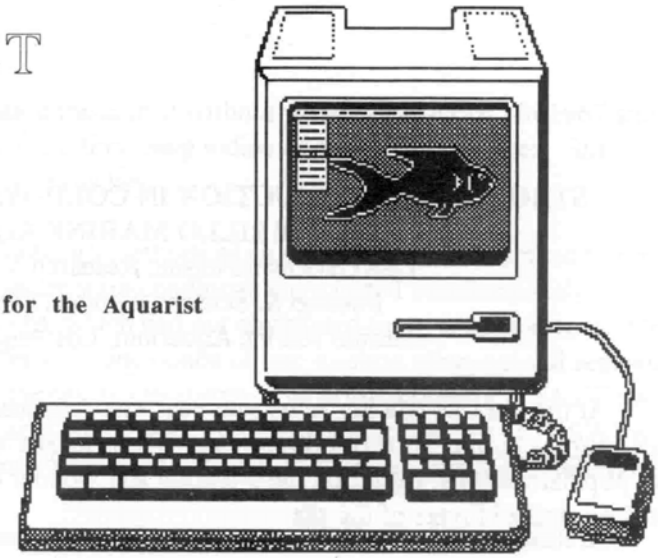

Thursday, December 29, 1994

Mr. Pete Mohan, Curator of Fishes
SeaWorld of Ohio
1100 SeaWorld Drive
Aurora, OH 44202

Dear Pete:

I thought that I would take this opportunity to advise you that a special message section and library has been set up on our expansion efforts on CompuServe with the Pets 2 Forum. In this forum we have set up a section dedicated to zoos and aquariums. We are making every effort to bring on line and make available to zoo and aquarium professionals, the various back issues of Drum & Croaker that we have been able to secure.

You may wish to bring this to the attention of your readers in a future issue of D&C. Should you or any reader of D&C wish to receive a complimentary CompuServe introductory package, please contact me directly. I can also be contacted via InterNet at 76703.4256@COMPUSERVE.COM.

Thank you for your time and consideration.

Cordially,

John R. Benn
Manager, FISHNET Forums

JRB/jb

STROBILATION INDUCTION IN COLD-WATER Aurelia aurita AT THE CABRILLO MARINE AQUARIUM

Lisa Gershwin-Nelson, Research Volunteer
Michael S. Schaadt, Exhibits Director
Cabrillo Marine Aquarium, Los Angeles, CA

At the Cabrillo Marine Aquarium near Los Angeles, we have been displaying moon jellies, Aurelia aurita, for about three years. These mysterious beauties are one of our more popular exhibits, capturing the attention and wonder of young and old, student and professor, and all lovers of the sea.

In order to properly appreciate the beauty and graceful movements of these animals, we display them in a planktonkreisel, a special aquarium developed by Greve (1968) and modified by Hamner (1990). The circular motion of the gentle current keeps the jellies suspended in the water, similar to their natural environment. We follow husbandry methods described by Abe and Hisada (1969), Caughlan (1984), Sommer (1986), and Norton (1993).

Aurelia is not only mesmerizing to look at, but fascinating to study. It is a cosmopolitan scyphozoan, appearing in nearly every ocean and sea of the world. Like many other cnidarians, Aurelia displays an alternation of generations in its life cycle (Hyman, 1940) (Fig. 1). The medusa stage reproduces sexually, producing a zygote which metamorphoses into a planula larva. The planula is planktonic and eventually settles on a substrate, where it matures into a polyp, called a scyphistoma, resembling a tiny sea anemone. This sessile asexual stage can undergo two different types of cloning. It can bud off tiny little replicates of itself, more polyps, or it can undergo a process called strobilation, in which the polyp elongates and differentiates by transverse fission into a stack of tiny disks. These disks, called ephyrae, are then released sequentially, and drift off to grow into the mature medusae.

As we observed strobilation, we began to wonder what factors were actually triggering the process. We also began to think about what would happen if strobilation stopped in our tanks. We need to be able to count on a constant supply of jellyfish for our display and research. Sometimes we had a limited amount of strobilation, other times we had intense strobilation blooms, and sometimes no strobilation at all for long periods of time. Surely, we thought, there must be some way of controlling this process.

We spoke at length with experts on the care and keeping of Aurelia. Freya Sommer, at Monterey Bay Aquarium, had been extremely helpful in getting us started with our first jellies. She said that her animals strobilated whenever there was a cold-spike in the seawater system. Even though our animals were obtained from her stock, this did not appear to be effective when we tried it under controlled conditions. We also spoke with Dr. Dorothy Spangenberg who, for the past thirty years, has so thoroughly studied Aurelia strobilation that one cannot mention the animal without praising her work. In 1967 she published a paper on strobilation induction using iodine added to the seawater. She suggested that this method would be the key.

We decided to try Spangenberg's methods as closely as possible and in addition test some other variables. Twelve separate conditions were tested simultaneously (Table 1). We put groups of polyps, which had not strobilated for at least one year, into covered petri dishes with approximately one ounce of test solution using natural seawater and artificial seawater at three different temperatures. The artificial seawater (ASW) we chose was Instant Ocean, because it was readily available. Natural seawater (NSW) was obtained from an offshore location (San Pedro Channel, CA), aged, then used unfiltered.

Iodine molarity was achieved by adding iodine to ASW or NSW to result in solutions 10^{-5}M. The experiment was conducted for a period of four weeks on each group, during which time the animals were not fed, the solution was not changed, and, except for minimal observation times, the temperatures were not adjusted. In order to adequately assess changes in strobilation status, the dishes were checked under a dissecting microscope three times per week. Petri dishes were divided into quadrants, in order to accurately identify the status of specific polyps.

Some interesting things happened as we replicated Spangenberg's work. Strobilation occurred; in fact, more abundantly than we expected, but not under the same conditions as Spangenberg's. Whereas her warm-water (Gulf Coast stock) Aurelia required cold-water (19° C) preconditioning followed by iodine induction in even warmer water (27° C), we found that our cold-water animals (from Japanese stock) responded differently. Our treated Aurelia showed very low strobilation percentages when kept at room temperature in test solutions, in fact lower than untreated groups. However, among test groups in the ambient seawater temperature (15° C), that to which they were already acclimated, we observed very high strobilation rates, in some trials as high as 86 percent (Table 2).

Interestingly, the animals tested in NSW with added iodine strobilated at higher rates than those in ASW. The percentages for ASW with iodine and ASW without iodine were identical, presumably because the iodine already present in the ASW was sufficient to induce strobilation.

Iodine appeared to be an important factor in strobilation induction. But iodine alone neither guaranteed strobilation nor did its absence prevent it. The most important factor appeared to be temperature. Dishes with water type and iodine concentrations equal, but varying temperature showed remarkable differences in strobilation rates.

It is extremely important to note also that induction occurred while animals were isolated in a small amount of water, "stewing in their own juices," as Dr. Spangenberg is so fond of saying. We had tried iodine induction previously, by adding the ions directly

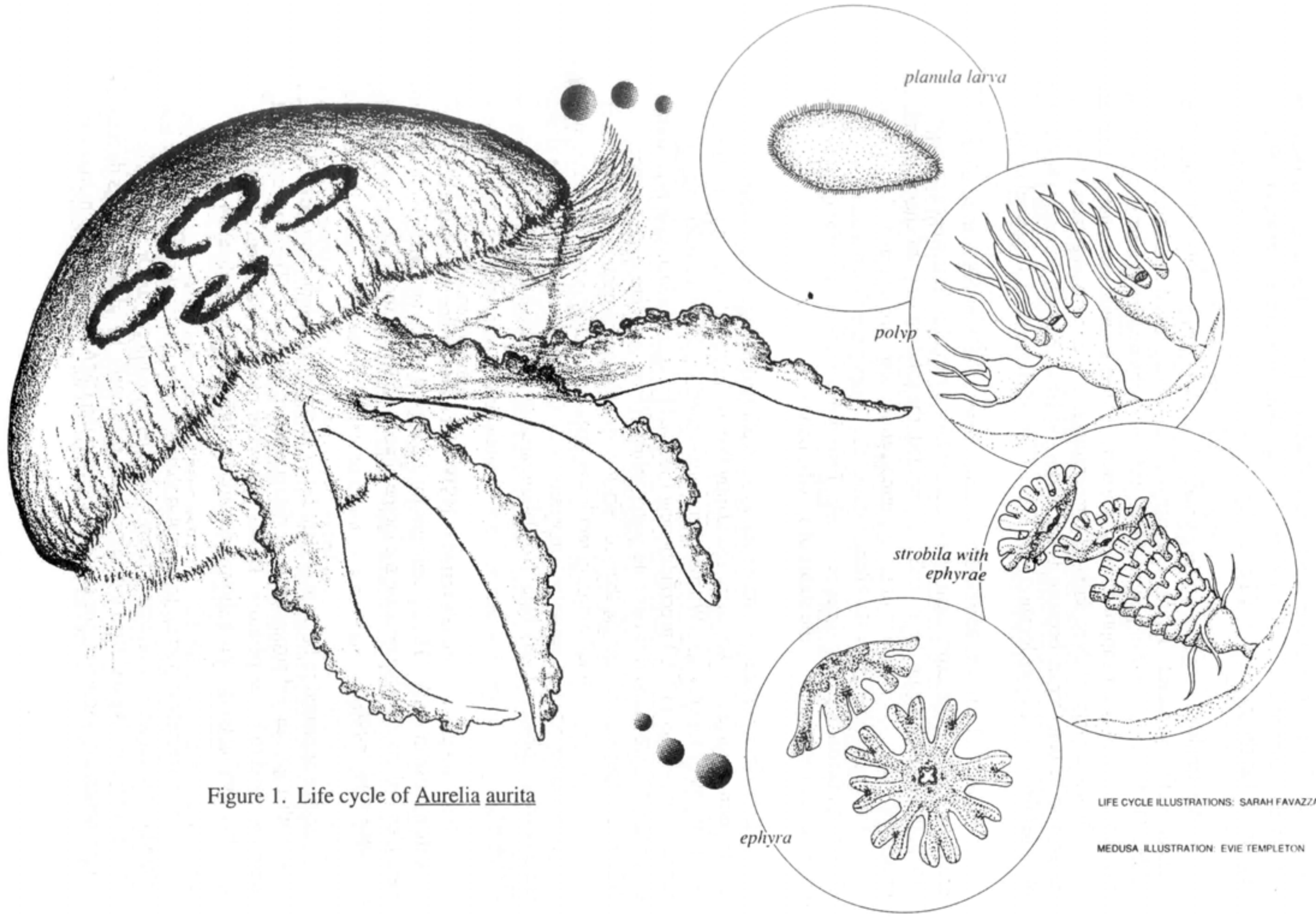

Figure 1. Life cycle of Aurelia aurita

LIFE CYCLE ILLUSTRATIONS: SARAH FAVAZZA

MEDUSA ILLUSTRATION: EVIE TEMPLETON

into the aquarium. However, the charcoal filters in the CMA filtration system may have removed the iodine resulting in concentrations below the threshold needed to induce strobilation.

We have no more worries about fresh exhibit stock. With Spangenberg's methods, adjusted slightly for our cold-water Aurelia, we have ephyrae just five days away at any time of year. With proper care the ephyrae grow into the ever so popular adult medusae of the CMA planktonkreisel exhibit.

Acknowledgments: The authors extend warmest regards and gratitude to the staff and volunteers of Cabrillo Marine Aquarium for their unyielding support and encouragement. Deepest gratitude also to Dr. Dorothy Spangenberg and Freya Sommer, without whose guidance and kindness this work could not have been accomplished. And very special thank you's to Sarah Favazza and Evie Templeton for artwork, Tammy Mangione for word processing, and to Dr. Izzy Goodman for elemental iodine.

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Table 1. Conditions:

Seawater Type	Iodine	Temperature
ASW	Added	Refrigerated (4º C)
ASW	Added	Ambient (15º C)
ASW	Added	Room Temp (23º C)
ASW	Not Added	Refrigerated
ASW	Not Added	Ambient
ASW	Not Added	Room Temp
NSW	Added	Refrigerated
NSW	Added	Ambient
NSW	Added	Room Temp
NSW	Not Added	Refrigerated
NSW	Not Added	Ambient
NSW	Not Added	Room Temp

Table 2. Results:

Conditions	#Tested	#Strobilated	%Strobilated
ASW/Iodine/Refrig	9	0	0
ASW/Iodine/Ambient	159	126	79
ASW/Iodine/Room Temp	162	8	5
ASW/Refrig	10	0	0
ASW/Ambient	158	125	79
ASW/Room Temp	167	12	7
NSW/Iodine/Refrig	9	0	0
NSW/Iodine/Ambient	134	115	86
NSW/Iodine/Room Temp	110	2	2
NSW/Refrig	12	0	0
NSW/Ambient	131	20	15
NSW/Room Temp	111	0	0

SOME UNUSUAL DEATHS OF COBIA, *Rachycentron canadum*, IN DISPLAY TANKS

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The cobia, *Rachycentron canadum* (Linnaeus), is a cosmopolitan fish in tropical and temperate waters of the world, and has also been known by the common names of ling, lemonfish, jackfish, crab-eater, cabio, sergeant-fish, "bonita," "black bonita," and coalfish in North America. As it is one of the fastest growing local fish it may have potential as an aquaculture species. Deaths while in tanks would be of interest to any future aquaculture of this species. Four cases are reported here.

Case 1

During the summer of 1985 a cobia was added to a 42,000 gallon tank in which two large sharksuckers were already established. As the cobia grew larger the sharksuckers switched from attaching to large red drum to the larger cobia. On January 23, 1987 it was decided to remove the two sharksuckers which were severely irritating the cobia, causing lesions and irritation that resulted in the cobia trying to rub them off on objects in the tank. When two divers speared the offending sharksuckers the cobia reacted quickly, slamming into a large trawl board, dislodging the top board. Nothing much was thought of the incident until March 8, 1987 when it became apparent that the fish was slowing down, eating less, and kept the right operculum flared. This behavior continued until the fish was found barely alive on June 15, 1987. After removal to a back-up tank, it died within an hour. A necropsy revealed a ruptured spleen with three large (76 x 42 x 10, 63 x 24 x 6, 33 x 29 x 6 mm) clots and two sacks of non-clotted blood originating from the ruptured spleen. It was concluded that death was the result of a ruptured spleen from hitting the trawl board. The fish weighed about 50 pounds.

Case 2

A small (8" TL) cobia was put on display on August 12, 1985 and moved four times to larger tanks as it grew. It was placed in the 42,000 gallon main tank on August 1, 1987. The fish was removed from display twice for treatment with 1:4000 formalin for 50 and 75 minutes for the gill monogenetic trematode *Dioncus rachycentris* Hargis, 1955. This fish also slowed down and ate less about a month prior to death. Upon death on November 25, 1987 a necropsy revealed an intensely pigmented green liver due to back-up of bile. Dr. Tom Bell (Mississippi State University Veterinary School, personal communication) indicated that blockage of the bile duct leads to liver dysfunction. With blockage the level of bilirubin (a biliary pigment) increases, possibly resulting in the staining of tissues by bile. Biliverdin, a green pigment, is a degradation product of bilirubin. The obstruction had apparently been going on for some time because the liver was green, indicating a large concentration of biliverdin. Death was attributed to inflammatory conditions of the bile duct whereby the duct became thickened and fibrotic, leading to duct blockage and back-up of bile, causing liver dysfunction and death. The fish weighed about 50 pounds.

Case 3

A cobia of about ten pounds was added to the main tank on August 16, 1988. This was the most aggressive cobia in feeding that we have had, rushing around the tank to take most of the food introduced. A decline in feeding and slowing down were first noticed about two months prior to death on December 15, 1990. A necropsy revealed severe hemorrhaging in the pancreas area, the pyloric caeca area, and surrounding parts of the digestive tract, plus some hemorrhaging in overlying abdominal muscles. This was presumed to be the result of a strong blow form another large fish in the tank (red drum, nurse shark, gag) or the fish hit an object (rocks or trawl board) in the tank. The fish weighed almost 65 pounds.

Case 4

On June 21, 1993 a small (5" TL) cobia was added to a 210 gallon tank. On August 17, 1993 the abdomen was noticeably enlarged, but the fish was still eating. On August 23 and 24, 1993 the coelomic cavity was punctured and a cloudy fluid was expelled. The fish was dead on August 26, 1993; it was nine inches long. A necropsy revealed a "ball" of coral (about 30 mm in diameter) in the intestine just prior to the vent. The fish had been eating #4 sinking trout chow pellets, floating flake food, and cut-up squid and fish. Apparently the fish had ingested crushed coral (2 x 2 x 2 to 4 x 4 x 7 mm) when trying to ingest the trout chow pellets lying on the coral substrate in the tank. The coral had passed through the digestive tract and jammed up into a "ball" at the anal sphincter. The intestine was greatly distended and irritated at the "ball" of coral. It is not known if the blocked intestine or our punctures caused the death.

Ingestion of rocks or coral leading to death has been documented in our aquarium for red-eared slider turtles and mud sirens. In these cases the problem was corrected by deleting sinking trout chow pellets and changing to floating food pellets.

The cobia appears to be susceptible to blows leading to internal bleeding and death. Sinking food pellets should not be fed to small cobia and some other species to prevent ingestion of substrate.

USING THE HACH DR/2000 SPECTROPHOTOMETER TO DETERMINE THE RELATIVE WATER CLARITY OF AQUARIUM SYSTEMS

Jay Hemdal, Curator of Fishes

The Toledo Zoo

The Hach DR/2000 spectrophotometer has gained wide acceptance with public aquarists as a water quality assessment tool. Its ease of use, portability, relative low cost and wide range of available test parameters have all contributed to its favor. One of the more useful built-in measurements is method number 8025; True and Apparent Color. The following outlines some minor modifications to the published Hach method, a case history, as well as proposed means to interpret the results.

The Hach true/apparent color measurement technique photometrically compares a given water sample to a blank of "zero" value, and gives the user a means to compare relative water clarity and color. Apparent color is a combination of dissolved coloring agents such as organic wastes, certain inorganic compounds, and tannins (sometimes collectively called "gelbstoff") combined with any suspended matter. This is the "real" measurement, in that this is what one's eye perceives when viewing a given aquatic exhibit. True color is derived from a sample which has been pre-filtered or centrifuged to remove the suspended particulate matter. This measurement gives the user an idea of the potential benefit which might be gained through the use of carbon filtration or partial water changes designed to remove or dilute the gelbstoff concentration. The relation of these two values is important to understand; a high apparent color combined with a lower true color reading indicates that the mechanical filter of a given system is not sufficient to achieve proper particulate filtration of the water volume. A high true color, nearly equal to the apparent color indicates that mechanical filtration is sufficient, but that excessive gelbstoff is present, and should be removed by chemical filtration or water exchange. A true color reading greater than the apparent color reading indicates some error in the test procedure; for example not insuring that the outside surface of the sample cell is clean, or not pre-rinsing the filter paper to remove any loose fibers.

One might think that the Hach DR/2000 method number 8006 for suspended solids could be used in place of the apparent color reading to determine relative aquarium water clarity. It is my experience that the resolution for this particular test is not fine enough for practical use in aquariums; even the most obviously cloudy water system may not register in more than the lower .5% of the test scale, allowing possible operator error to virtually negate any meaningful reading.

The Hach DR/2000 method number 8025 is used to determine the true and/or apparent color of any water sample with results given in platinum-cobalt (PtCO) units in a range of 0 to 500. The following are suggested modifications to the Hach company's published methods which may make the results of this testing procedure more germane to public aquarists:

Step 1) For aquarium use, an aspirating filter does not seem to be required as is indicated. A simple "cone-folded" filter paper of appropriate pore size inserted into a funnel will give good results with less effort. Hach suggests that for apparent color measurements, the deionized water for use as a blank should not be filtered. I disagree in that deionizers seem to vary in the turbidity of their output, and as public aquarists, we are interested in comparing our actual tank water clarity to that which is the best that could possibly be obtained. For this reason, I pre-filter both true AND apparent color blanks when running this method.

Step 7) Despite the fact the DR/2000 is a mostly solid state device, the light source is a filament bulb, and as such, may be affected by the heat produced during its operation. I suggest that the DR/2000 unit be turned on, and the program number be entered, at least 15 minutes prior to taking any measurements to minimize any "drift" which may be incurred while the bulb reaches its final operating temperature.

Steps 11 & 12) The physical act of removing the blank cell and then inserting the sample cell to be tested may cause an error in the test procedure in some cases. To reduce this error, I suggest that one should re-insert the blank cell into the unit after the reading is taken to insure that it still reads zero. If the blank cell does not read "0. Units Pt COLOR" upon reinsertion, the DR/2000 should be re-set by again performing step 11. In cases of very low apparent color readings, this modification may be required multiple times until the most stable reading is achieved.

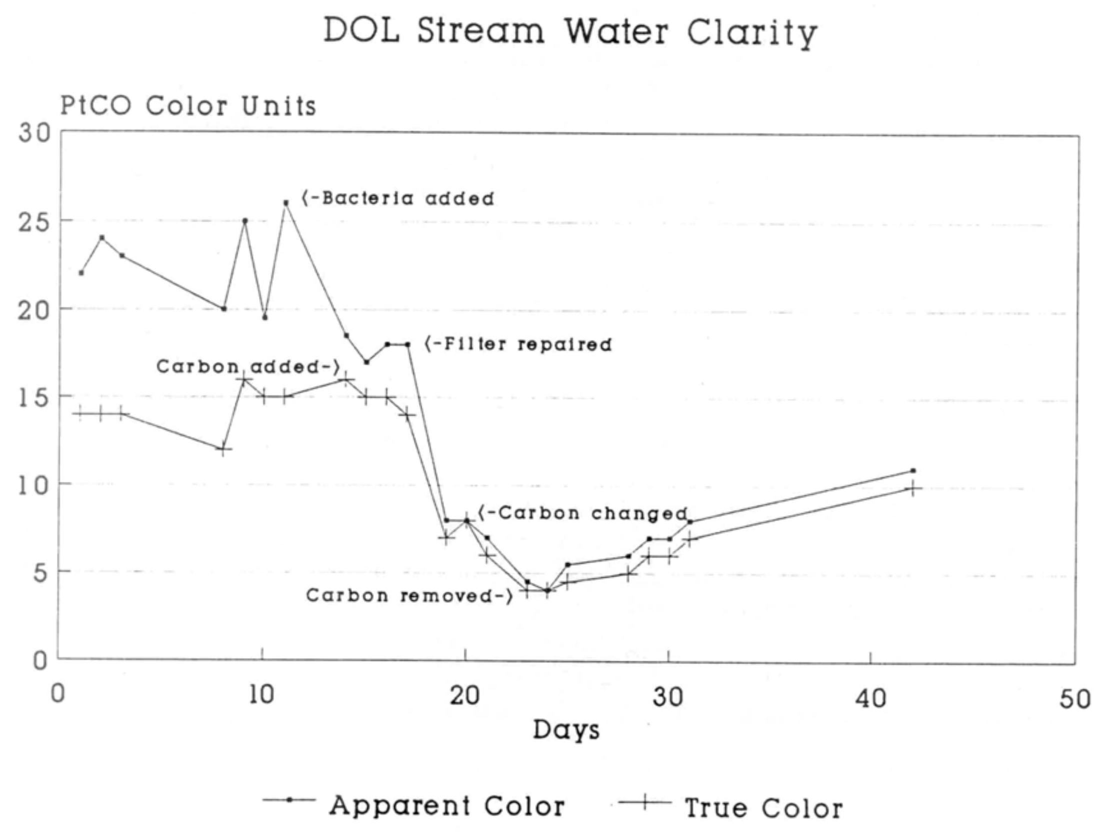
Finger smudges or lint on the outside of the sample cells, or air bubbles stuck to the inside of the cell will affect accuracy, especially for results towards the low end of the testing scale.

An exhibit at the Toledo Zoo in the Diversity of Life building had a history of chronic water clarity problems. This exhibit, called the DOL stream, is a 2000 gallon gunite exhibit housing native fishes and turtles and filtered by a rapid sand filter. As shown by the graph, I approached solving this water clarity problem by first gathering ten days of baseline data for both true and apparent color readings. I discovered that this system had very high apparent color (20 to 26 units) and moderately high true color (14 to 16 units). This indicated to me that the mechanical filtration was not sufficient and that there was an excessive amount of gelbstoff in the water. The husbandry regime of the system was discussed with the keeper in charge, and some minor modifications were made to the back wash and feeding schedules. On day 11, a proprietary bacteria culture (Alken Clear-Flo 1200) was added. On day 15 a temporary carbon filter was added to the system. On day 16, a worn out spider gasket on the sand filter multi-port valve was replaced and the filter sand changed. The readings on the spectrophotometer closely mirror these changes made to the system operation, even to point of showing when the carbon in the filter was replaced on day 20. The temporary carbon filter was removed on day 23, and the true color readings gradually began to increase (something which could be rectified by installing a permanent carbon filter). Note however, that the apparent color reading stays nearly equal to the true color reading after the filter was repaired. This shows that the suspended solids are at minimal levels, indicating that the repairs to the filtration system were successful in reducing turbidity in the system.

In interpreting the results of this test procedure in other systems, it is important to understand how other factors may influence perceived water clarity of a given system. An aquarium front that has reflections on it from strong ambient room light, or other nearby displays will always seem "less clear" than the same tank viewed from a darkened public area. Glass viewing windows impart a green hue to the water which is not seen with acrylic windows.

In systems where the true and apparent color readings are equal but elevated, (indicating low turbidity but high gelbstoff) some types of aquarium lights such as halogens bulbs, seem to cause the gelbstoff to show up more than high temperature metal halide bulbs, for example. Obviously, the lateral viewing distance of a tank affects the overall perceived color of the water. A ten gallon aquarium with a reading of 5 PtCO true color units may seem "clear", but that same water in a 20 foot wide shark tank will look distinctly yellow. For many larger systems, .5 to .75 PtCO true color units per foot of tank width is a good target to try for.

The true color reading subtracted from the apparent color reading gives the relative turbidity of the system. This reading should be less than .3 PtCO units per foot of tank width. Tank lighting affects the perceived turbidity as well. A bright focused light source above the tank (such as a metal halide pendant lamp) will scatter when it hits free floating particles, causing the tank to seem more turbid.



AQUARIUM HUSBANDRY OF THE GIANT PACIFIC OCTOPUS

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Introduction

The first known public aquarium was the fish house at the London Zoo, which opened in 1853 (Gosse, 1854). Later in the Victorian era public aquaria became quite popular and were constructed throughout Europe (Gilbert, 1970). Early records confirm that these aquaria displayed octopus: Lee (1875) writes of octopus in aquaria in Boulogne in 1867 and at Brighton in 1872. He states that "an aquarium without an octopus was like a plum-pudding without plums." It is probably not coincidental that the rise in popularity of octopuses in aquaria corresponded with the publication in 1866 of Victor Hugo's lurid description of an octopus attack in Toilers of the Sea. It is interesting to note that these early aquarists had some of the same problems with octopuses (such as their tendency to hide) that beset the modern aquarist (Lee, 1875).

Today, octopuses continue to intrigue the public in aquaria all over the world, and to a lesser extent in home aquaria. There are many reasons for wanting to keep and display octopuses in aquaria. Their human-like eyes, alien body shape, and role as the most intelligent invertebrate, all contribute to their popularity. A poll of visitors at the Seattle Aquarium showed that octopuses are one of the most popular aquarium animals (Frederick Lighter, Marketing Specialist, Seattle Aquarium, pers. comm.).

Aquariums generally like to display large octopuses, animals somewhat close to the "monster octopus" of film, fiction and legend. The largest octopus species is the giant Pacific octopus, Octopus dofleini. It grows to a documented size of 70 kg with an arm span of seven meters. Because their arms are rubbery and easily stretched (particularly in anecdotal accounts!) weight is a better indication of size than arm span.

In years past collectors have been able to obtain and sell giant octopuses to aquariums around the country. Recently, several collectors have gone out of business and state regulatory agencies have tightened the rules about shipping animals across state lines, making giant octopuses harder to obtain. In the interests of increasing health and longevity of giant octopuses in aquariums, this seems like a good time to summarize what we know about the husbandry of the animal. Information given here is drawn from references and personal experience at the Seattle Aquarium.

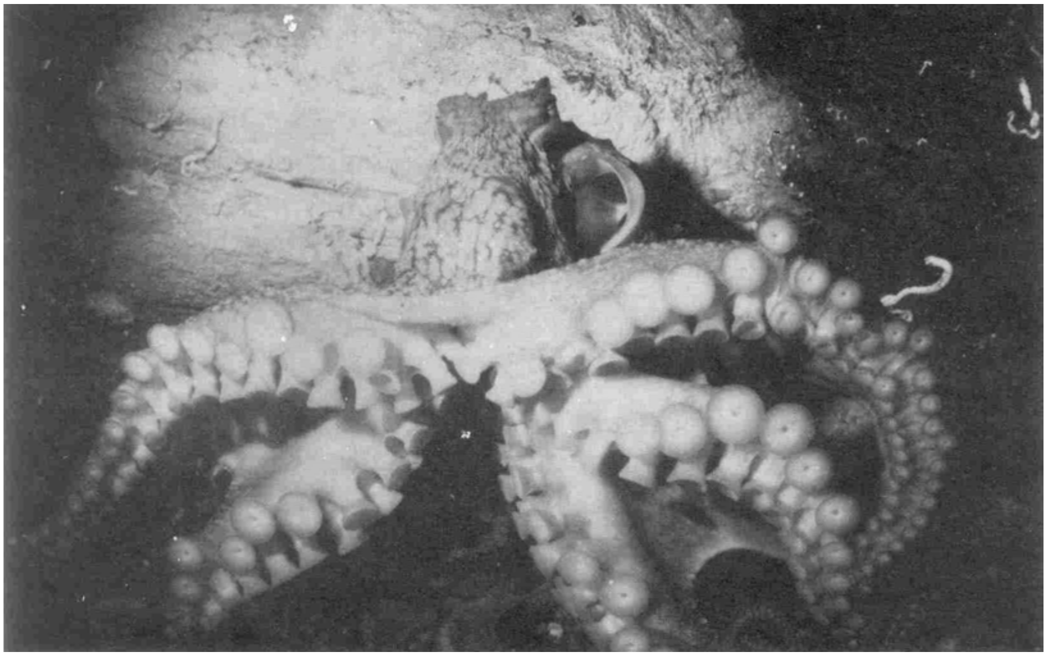

Photo Caption: A giant Pacific octopus (Octopus dofleini) in a Seattle Aquarium display tank.

Giant octopuses grow to a large size in a relatively short life span, feeding on crabs, bivalves, fish, and fresh carrion. They can grow up to two percent by weight per day. They reach sexual maturity at about fifteen kg, when mating occurs. The female guards the rice-like eggs until they hatch, and the male dies within several months of mating. Good accounts of the natural history of O. dofleini can be found in High (1976) and Hartwick (1983).

O. dofleini lives longer than most other octopuses, but it is still a short-lived animal, living only 4-5 years from egg to adult (High, 1976). In contrast, tropical octopuses live a much shorter life. For example, O. briareus lives only 10-17 months (Hanlon and Wolterding, 1989). Because of their longer life span, O. dofleini make good aquarium animals, giving the aquarist and public more time to enjoy the animal, become acquainted with an individual animal's habits, and less need to collect animals from the wild.

Obtaining the Animal

There are several ways to obtain octopuses for an aquarium. They may be bought, although there are currently few collectors who can guarantee shipment. Octopuses may be donated by local divers or fishermen. Perhaps the strangest donation the Seattle Aquarium ever received was a 12 kg octopus caught by an out-of-town angler, fishing from the waterfront window of a nearby on-the-water hotel. Octopus may be traded from institution to institution. They may also be propagated, but this is usually expensive and labor-intensive (considering the current lack of available collectors for octopus, we may be re-thinking the costs/benefits of rearing them in the future). Assuming the resource is not affected or depleted, collecting animals from the wild is usually the preferable and most satisfactory method, as the condition, size, and species of the animal can be chosen.

Collecting O. dofleini for the Seattle Aquarium is usually not a difficult feat. It is commonly accomplished by diving. Timing and choice of dive site are important, as they are not seen during every dive. The Seattle Aquarium has a large cadre of staff and volunteer divers who report octopus sightings to the collectors, who then return to the site if an animal is needed by the Aquarium. The dens of O. dofleini are usually very evident (High, 1976), although these octopuses are frequently found out of their dens (see Kyte and Courtney, 1977).

If the animal is in a den it can be forced out by squirting a noxious chemical inside the den. In the past, a solution of copper sulfate was used by divers (High, 1976). Its use was deservedly banned, since it killed the octopus and all other invertebrates nearby. Chlorine bleach has also been used, is very effective, and seems to have little effect on the octopus (Bronikowski, 1984), although I have observed it to kill many other small invertebrates near the den. It is also presently outlawed for the taking of octopus. We currently use a legal fish anesthetic, although it is somewhat less effective than bleach.

We generally try to choose smaller animals to collect for display purposes, due to the life span of the animals. A large animal may only live a few more months. A smaller animal of two to five kg may live a year to eighteen months in captivity.

Once coerced out of its den we try to wait until the octopus is crawling on sand or gravel, or is swimming, so it won't have anything to hang onto. It is then wrestled into a divers' mesh bag. These animals are large and strong, and can hold onto rocks with surprising strength and tenacity. When brought to the surface, the animal is placed in a large ice chest or other insulated container for transport back to the Aquarium. The choice of transport container depends on the size of the animal; up to a 10 kg animal can be transported in a large ice chest filled with chilled seawater. If transport time is less than 1 hour the water is not oxygenated. For longer trips pure oxygen is bubbled into the chilled water. We have successfully caught and transported octopus up to 38 kg using these methods.

Upon arrival at the Aquarium the animal is transferred to a holding area where it is weighed and measured. Excessive handling of the animal is avoided, especially with rough nets, as its skin is delicate and prone to injury from abrasion (see Hulet, et al. 1979). It is then placed in a suitable holding tank. Octopuses from questionable sources such as fishermen are given supplemental oxygen for a few days. We have found this to be of great benefit in curing animals of questionable health.

Shipping

These northern Pacific octopuses seem very amenable to shipping to other parts of the world. The methods that we use are similar to those used by other aquariums and collectors (see Prescott and Brousseau, 1962; Bronikowski, 1985). Prior to shipping, the animal is not fed for two days to allow any food to be totally digested (feces in the shipping water harms the water quality). The animal is placed in a large plastic bag, at least 3 ml thick, with enough seawater to equal approximately 2-10 times the volume of the octopus, eg. a 10 kg octopus will require about 20 kg of water. The size of the bag selected should be large enough to include four times (or more) as much gaseous oxygen as water. The bag is then sealed inside two other bags of the same size which are also sealed. This triple-bagging eliminates the possibility of leaking bags or the animal puncturing the bag by chewing through it (see Ballering et al, 1972).

If the octopus has inked in the water during the above process, the whole procedure is repeated with clean water. Small O. dofleini are far more likely to ink than larger animals, which seem very loathe to ink. We have never had an O. dofleini larger than four kg ink in a bag, while at least 50% of the smaller O. rubescens have inked while being packed. It is not clear whether inking in a shipping bag is really fatal to an octopus. Since octopuses frequently ink when they die it is difficult to tell if the ink caused the death or was the result of it, but Thomas (1978) claims ink may be toxic to an octopus in closed systems.

Once the bag is filled with oxygen and sealed, it is placed in an appropriately-sized cardboard box lined with 2.5 cm thick styrofoam (polystyrene) for insulation. At least two ice packs are added to keep the shipment cold, and the box is sealed. The ice packs are usually wrapped in newspaper to prevent their sharp edges from puncturing the plastic bag.

This method of shipping octopus is good for transportation times of up to 24 hours. We have shipped four O. dofleini from Seattle to Sweden with good success (one animal died due to a transit time of more than 36 hours caused by a flight delay). Airline schedules and reserved cargo space must always be arranged well ahead of the shipping time. Boxes must always be labeled clearly with the shippers' and shippees' names, addresses, and phone numbers, and the fact that they contain live animals.

Upon arrival, the bag containing the octopus should be floated in its new tank water for temperature equalization, usually about 15 minutes. Another good practice is to add tank water to the bag after temperature adjustment and leave for another 15 minutes, to allow the animal to adjust slowly to any changes in water chemistry. After this has been accomplished, the animal should be allowed to crawl out into the new tank and the bag water should be discarded, as it will be loaded with wastes accumulated during the trip.

I like to hold a new animal off-exhibit several weeks before putting it on display to the public. This gives the animal a chance to adapt to captivity, to begin feeding on standard aquarium food, and to get used to human activity.

Aquarium Design for Octopus

I do not intend to go into basic aquarium operation. A multitude of books, articles, and journals deal with the subject in great and technical detail, such as Spotte (1979) and Clark and Clark (1964). Reviews of laboratory maintenance of octopuses, such as Hanlon and Hixon (1983), Boletzky and Hanlon (1983), and Boyle (1991) will also be of value. There are, however, far fewer articles in the literature dealing with maintenance of octopuses in public or private aquariums. Articles such as Prescott and Brousseau (1962), Thomas (1978), Bronikowski (1984), and Anderson (1987a) will form a good basis for the octopus aquarist.

It is preferred by far to keep octopus (or any other aquarium animals) in open systems with flow-through seawater, if at all possible. "Open systems are proven reliable and convenient" (Boletzky and Hanlon, 1983). This presupposes that the animal can survive in the available flow-through water and can withstand the ambient water conditions. Obviously, only aquariums located on or near a seashore can have this luxury, but Prescott and Brousseau (1962) suggest that octopus survive better in open systems. The Seattle Aquarium runs its temperate water tanks, including native cephalopods, on an open system basis. For a complete description of the Aquarium's seawater system see Anderson (1987b).

The display tank which holds O. dofleini is of all-glass construction, of 1100 liters capacity, cemented with inert silicone glue. O. dofleini to 18 kg have been kept in this tank. Larger O. dofleini could be kept in this tank but the public starts to complain about "a large animal in a small tank" when the animals are larger than about 15 kg. Plans are being made for a larger tank, capable of holding a 45 kg (100 pound) animal. In the past we displayed giant Pacific octopuses in a large ($1.6X10^6$ l) multi-species tank at the Seattle Aquarium, but these were taken out due to their predation on fish (see Anderson, 1991).

Octopuses can move or remove most anything in their tanks that isn't glued down or screwed down tightly. Our octopus tank has mesh undergravel filters cemented to the bottom of the tank over the two bottom drains, which go to external standpipes for drainage and water level maintenance. All plumbing is plastic PVC pipe. If internal standpipes are absolutely necessary in the octopus tank, a perforated PVC pipe of a larger diameter can be placed over the standpipe; the water flows through the perforated pipe then over the top of the standpipe, and the animal cannot pull out the standpipe. We have found such standpipe protection to be relatively octopus-proof. There are two drains and two water inlets into the display tank for redundancy.

Gravel in the O. dofleini tank is about 3 cm in diameter. With flow-through circulation, the gravel and undergravel filter provide little nitrification, but rather provide a naturalistic cover for the bottom of the tank, a cover for the bottom drain, and also a place for the breakdown of feces, uneaten food or sucker molts. The octopus can move the gravel around with relatively little destruction of the exhibit, and the aquarist can easily smooth it out and gravel-wash it.

In the back of the tank is a fiberglass backdrop made to resemble a rock wall. It fits very tightly into the back of the tank, to prevent the octopus from going behind the backdrop or pulling it out. Before a tight-fitting backdrop was installed, the O. dofleini was able to pull the gravel out from the bottom, squeeze under the backdrop, and hide behind it, thus avoiding the tank lights and exposure to people. One particularly retiring female octopus that continually pulled this stunt was named "Emily," for Emily Dickinson, who was notoriously shy. I had a very difficult time keeping this animal out in the open. I used a bristly stick, bright lights, prickly sea stars, and Astroturf®, all to no avail. A weak electrical prod, using a 9 volt transistor battery was finally successful. Thankfully, I soon obtained a tight-fitting backdrop that the octopus was unable to squeeze behind. Tight-fitting backdrops in closed system tanks may be a problem, as pockets of stagnant water may collect behind them, harming the water quality.

All openings to and from an octopus tank must be extremely well sealed, and in the case of O. dofleini, strongly sealed. These animals can exert considerable strength. An 18 kg animal we were holding had a plywood cover on it with 27 kg of weight on top. The octopus was able to slide the lid off far enough to escape. Tanks too large to be sealed may have a one-meter high wall around them covered with Astroturf[R] or burlap. Larger animals cannot climb as well as smaller animals. A 200 g octopus can climb the sides of a five gallon bucket, while a 40 kg animal can barely slither over a tank edge.

Water flow in the Seattle Aquarium's octopus tank is enough to provide a 1-2 hour turnover. This is probably more than absolutely necessary, but it contributes to the animals' health and success. Water quality in our flow-through system is always good. A recent test of the O. dofleini tank water showed water chemistry parameters of pH 7.7, dissolved oxygen 8.8 ppm, NH_3 0.03 ppm, NO_2 0.01 ppm, NO_3 0.30 ppm, and salinity was 28.0 o/oo. Temperatures range from 8-13°C. Such water quality parameters are highly acceptable according to Boletzky and Hanlon (1983).

Lighting for octopus tanks should always be at a reduced level compared to other aquarium tanks. Most octopuses are nocturnal or crepuscular. Our O. dofleini tank is lit by one 15 watt fluorescent fixture, which is further reduced by shading. As the exterior lighting in the invertebrate gallery is already reduced, 15 watts is quite adequate. We have not tried red lighting on the octopuses. Bronikowski (1984) had little success using red light. I find that if octopuses are properly acclimated to captivity before being placed on display, per Anderson (1987a), they usually adjust well to being active during the day under low lighting.

O. dofleini have been kept successfully in closed system aquariums. The systems for keeping O. dofleini in closed systems in two public aquaria are described in detail in Prescott and Brousseau (1962) and in Bronikowski (1984). Obviously, since O. dofleini grow so large, the tank must be sized accordingly. A closed system octopus tank needs to be larger than an open system tank to maintain oxygenation and waste removal. The Cleveland Aquarium maintains a 1900 liter display tank as part of a 9500 liter system and has kept up to a 39 kg animal in it (Bronikowski, 1984). Glodek and Kenny (1988) say there should be 135 liters water per kilo of octopus, a reasonable amount.

Well-cured cement or fiberglass seems to make good large octopus tanks. Tempered glass or acrylic are both suitable for glazing. I prefer glass because of its greater resistance to scratching. Water contact with metal should be avoided, especially with copper or copper alloys. Copper may kill octopus in a concentration of 0.02 ppm (Prescott and Brousseau,1962). Just two pennies in a 24 liter tank will create a copper concentration of 0.1 ppm in the water after 12 hours (Atz,1961). The metal monel should be avoided, as it contains copper and nickel. The aquarist may be tempted to use a good quality stainless steel in tank construction. It should be remembered that stainless steel achieves its stainless properties by the addition of nickel and other toxic metals. Even the best stainless steel should not come in contact with tank water.

An important component of closed-system maintenance of O. dofleini is the refrigeration unit. These animals must be kept at temperatures of 6-12^{o}C; 10^{o}C is ideal. Prescott and Brousseau (1962) claim that prolonged exposure to temperatures above 12^{o}C will cause death in O. dofleini. At the Seattle Aquarium the water may get to 13^{o}C for 1-2 months in the summer with no deleterious effects observed.

Refrigeration units should have no harmful metals in contact with water. Several companies make reasonably-priced units designed for aquarium salt water use, with titanium heat exchangers. Two that we have had experience with are Acri Tec, Inc. (7868 Silverton Ave, San Diego, CA 92126) and Sea Freeze (800 W. Holly, Bellingham, WA 98225). Both of these units in use at the Seattle Aquarium have proven durable and dependable. There are certainly many other companies that make these units; advertisements for them may be found in aquarium journals.

Water changes in closed systems are important to maintain water quality. At the Seattle Aquarium it is standard practice to replace one third of the water in our closed system tanks every two weeks, regardless of water quality, and more often if needed. Other aquariums have different practices. The Cleveland Aquarium changes 80% of their O. dofleini semi-annually and 30% of their O. briareus water per month (Bronikowski,1984). Thomas (1978) recommends changing 10% every week. Real seawater or water made from artificial sea salt may be used for water changes.

I highly recommend ultraviolet sterilization for keeping octopus in closed systems. UV sterilizers come in a variety of sizes, applicable for the home or public aquarium, and may be easily installed in-line with refrigeration units. For further details of UV sterilization, see Spotte (1979).

Feeding

The preferred food of O. dofleini is live crabs. O. dofleini fancies the Dungeness crab, Cancer magister. I prefer to transfer them to a diet of shell-less raw seafood, such as herring, smelt, squid, fish fillets, or clam meat (geoduck fillets). This minimizes the need to clean the bottom of the tank of crab remnants, which are visually unattractive and may contain bits of uneaten food. Although it may be more realistic to have an octopus "midden" outside the octopus den, food remnants may foul the tank. Food without shells is usually eaten completely, and if not, can be netted out of the tank. Regardless of what is fed, the diet should be varied, to give necessary nutrients and provide different stimuli to the octopus.

Feeding can be accomplished by spearing a piece of food onto the end of a thin plastic feeding stick touched to the octopus, which will grasp it. Feeder sticks can be easily made from long knitting needles or PVC welding rod. Usually, octopus will become accustomed to taking food from the aquarist's fingers. Amounts fed at the Seattle Aquarium are about 1-2% of the octopus' body weight per day. Octopus may grow 1% by weight per day; they are extremely efficient in their food conversion (Hartwick,1983).

Cleaning

I clean the gravel about once a month using a siphon tube to get rid of accumulated debris and sucker molts. In a closed system I would recommend doing this every two weeks. It can be done in conjunction with routine water changes. If an octopus sheds a large amount of sucker molts in a closed system tank, I would suggest siphoning them out as soon as possible to prevent their decomposing in the tank.

I clean the glass of the octopus tanks as needed, using sponge sticks, plastic scrapers, and razor scrapers (see Anderson, 1987b).

One must always be cautious in cleaning or working in an octopus tank to avoid being bitten by an octopus. All octopuses are venomous, but the venom varies in strength in different species, and some species are more prone to bite than others. While O. dofleini seems to be more loathe to bite people than other species, bites have occurred (Snow, 1970). No one has been bitten by O. dofleini at the Seattle Aquarium. It may be that since O. dofleini is so much larger than other octopuses, its handlers have a greater respect for its strength and large beak.

Conclusions

With proper aquarium design, maintenance, and feeding, O. dofleini can be easily kept in aquariums and can be highly visible to the public. The present Seattle Aquarium tank is too small for large octopus in the 80-100 pound range. Such animals are fairly common in Puget Sound. Plans are now being made to install a larger tank with better (three-sided) viewing to display larger animals. I particularly want to display an animal of 100 pounds or more. This should be a tank capable of showing these very real "monsters of the deep."

Acknowledgements

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1995 REGIONAL AQUATICS WORKSHOP (RAW)

The National Aquarium in Baltimore has volunteered to host the next meeting. Tentative dates are July 21-23, 1995.

For convenience, AZA Marine Fishes, Freshwater Fishes, and Aquatic Invertebrate TAG groups may hold concurrent meetings.

Contact Perry Hampton at (410) 659-4214 for more information.

A CASE HISTORY:
THE COLUMBUS ZOO DISCOVERY REEF

By
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and
Randall L. Kirschner, AIA
Project Manager, URS Consultants

The Columbus Zoological Park Association, located on land adjacent to the O'Shaunessy Reservoir north of Columbus, had long been interested in expanding its aquarium facilities to enable it to more effectively exhibit the several thousand specimens of aquatic animals housed there. With the passage of a ¼% sales tax increase by Ohio's Franklin County voters, a grant from The Columbus Foundation, and through major donations by National City Bank, Dispatch Charities and Red Roof Inns, the project became viable.

In 1990 the Zoo retained URS consultants to provide an independent review of the conceptual design prepared by another designer for the proposed remodeling and expansion of the zoo's aging aquarium building. The objectives of the study were to validate the constructability of that design, to evaluate its construction cost budget, to evaluate the existing conditions of the building, and adjacent site and to describe readily apparent deficiencies or obstacles to the implementation of the proposed phasing plan.

The study revealed multiple significant impediments to the implementation of the original design. These included conflicts between the existing roof structure and both the proposed exhibit design and phasing plan. To avoid these conflicts the existing roof structure would need to be removed and replaced with a new, higher roof structure with longer spans. To accomplish this, nearly half of the existing aquarium would need to be gutted during the first phase. With insufficient flex space available in the aquarium or elsewhere at the Zoo, many existing exhibits and specimens would need to be sold or surplused. Construction activities within the aquarium building would likely jeopardize the health of the remaining collection and inconvenience Zoo visitors and staff. Since so little of the original building would be saved by the original design it was not clear what advantage would be gained by utilizing that approach.

In its report URS Consultants recommended two new construction alternatives estimated to save either $400,000 or $800,000, respectively, over the planned remodeling/addition approach. The difference in savings depended upon whether the construction would be phased over a period of years or built all at one time. The new construction approach had several advantages. It allowed for optimizing design options and future flexibility; allowed more room for exhibits; eliminated the cost of temporary partitions, moving and storage of existing exhibits; allowed "back of the house" activities to be segregated in areas away from visitors; allowed higher ceiling heights for ease of husbandry activities and tank maintenance; and allowed for easier phasing of construction should funding be restricted. As it happened, funding for the larger Project was not feasible, therefore as the Zoo concluded that phased construction was in its best interest. In its report, URS

Consultants set forth a construction budget for Phase I of the new facility at $3.45 million.

A few months later URS Consultants was selected by the Columbus Zoo to provide architectural and engineering services for the new aquarium building Project. The Zoo established a construction budget of three million dollars and a project budget of $3.5 million. URS Consultants teamed with The Larson Co. of Tucson, Arizona for exhibitry consultation and construction, and Kramer, Chin & Mayo of Seattle, for aquatic life support consultation. A series of meetings was held with Zoo curatorial staff, Zoo Administration and Board members and the URS team to determine and develop the concept for the new facility. The primary exhibit philosophy was to promote marine conservation through public education by use of flexible realistic exhibits that would stimulate the visitor's interest. The idea that resulted from the meetings was a recreation of a marine ecosystem, initially named "Life on an Atoll." Before the end of construction, this name was changed to "Discovery Reef" so as to be less confusing and more recognizable.

A whole series of exhibit experiences was planned beginning with one describing "Water as the basis for life," and a explanation of "What is coral?" This would be followed by an exhibit depicting an atoll in the Maldive chain of islands in the Indian Ocean. The visitor's journey would continue through mangrove and eel grass bed communities to a theater where an educational movie would prepare the visitor for the trip to the next series of exhibits. The movie would introduce the visitor to basic concepts of coral reef biology and ecology, while explaining the typical associated communities which the exhibit sequence would follow - beach, mangrove, grass beds, reef flat, crest, and fore reef. Following the movie the visitor would encounter the reef flat including a 'hands-on' tidal touch pool. Here visitors would receive instruction from Zoo and volunteer education staff while controlled handling of marine invertebrates would be permitted. The transition between the reef flat and the reef crest would be accomplished through the illusion that the coral and rockwork of the reef flat extends through the walls of and into the main exhibit. The main exhibit, a 100,000 gallon reef exhibit would become the centerpiece of the aquarium and feature a fantastic display of rockwork and over 1,200 pieces of artificial corals covering over 64% of the available surface area thus giving the exhibit a very realistic appearance of dense coral growth. Plantings of the artificial corals would depict the zonation and groupings of species typically found on a coral reef from this region. Careful consideration would be given to creating overhangs, swim throughways, and vertical profile to provide escape avenues for smaller species to be introduced into the mixed-species exhibit. Beyond the reef face the visitor would continue out into the open ocean where rays and sharks appear up from the depths. The sills of the exhibit's viewing panels follow the downward slope of the ramp that allows the visitor the transition from shallow to deeper water by walking in front of increasingly larger panels. Finally, the visit would end with a look behind the scenes through a porthole into the aquatic life support equipment area. This would be positioned along the exit ramp along with a brief video and graphics highlighting marine conservation issues and efforts.

Of equal importance was the necessity that the building be easy to maintain and allow for ease of animal care by the aquarium's staff. The design provided excellent husbandry access and circulation that minimized the need for staff to cross visitor circulation. To resist the corrosive effects of saltwater and high humidity, the building's construction minimized the use of metals. Exterior walls are gray and charcoal split face masonry with glass block accents. Mezzanine floors are precast concrete. Epoxy coated rebar and DCI concrete admixture are used to fight corrosion in

Photo of rear elevation/service area taken by R. Kirschner, URS Consultants

Photo of main entrance taken by Randy Kirschner of URS Consultants

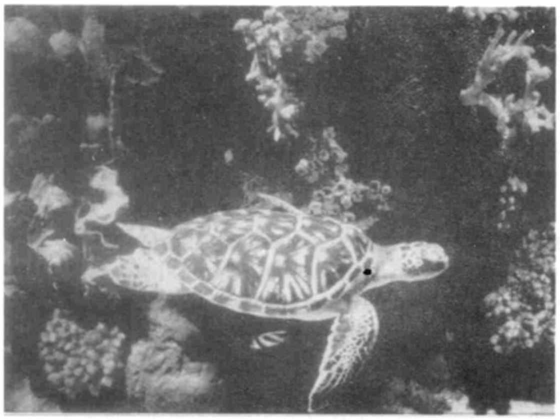


Photo of Sea Turtle taken by Michael Pogany of the Columbus Zoo.

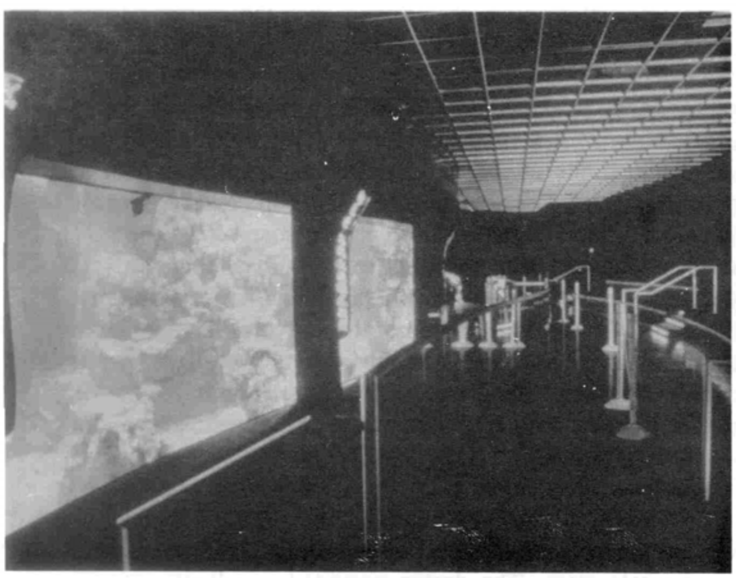
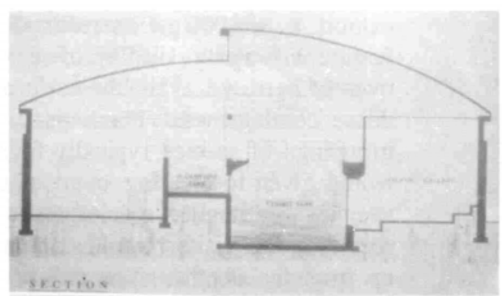


Photo of Discover Reef Exhibit taken by Michael Pogany of the Columbus Zoo



Building section by URS Consultants

concrete walls and floors. The curved roof structure is tongue and groove cedar planking over large wooden bowstring trusses spanning forty three feet. Stairs, catwalks, and doors throughout the facility are made of fiberglass reinforced plastic, as is much of the life support system. HVAC duct work is fiberglass reinforced plastic or PVC coated metal. Epoxy coatings are used throughout the facility for improved maintenance and corrosion resistance.

Space for an animal feeding kitchen, diver preparation room, office, and a modest water quality laboratory were provided in the design but were constructed by the Owner after opening to save construction costs. Three off-exhibit rooms were provided as quarantine/holding space for new arrivals. Two rooms, approximately 12' x 20', were dedicated to fish, and a third, approximately 12' x 18', housed invertebrates. Each contains several banks of tanks and pools with their own separate lifesupport systems. The main exhibit also has a 12' diameter 5,000 gallon quarantine pool attached by a hidden transfer chute. This pool can be isolated by way of a water tight door and run on its own dedicated lifesupport system or connected by means of a slotted grate and engaged on the main exhibit's lifesupport system. Thus it can be used for quarantine or for isolation and grow out. A one ton monorail is positioned from above the tank to a vehicle unloading area and is designed to facilitate the handling of large specimens, equipment, and exhibitry components.

A separate initial quarantine facility was set up in an on-grounds warehouse. This set-up accommodated the quarantine and holding space requirements of over 1,400 specimens, as well as, bacterial biological start-up cultures for the new filters and beds. Specimen acquisition began approximately six months prior to opening and continued until about 45 days prior to the first scheduled animal introductions. The quarantine protocols and set-ups used were modified versions of those used at The National Aquarium in Baltimore and The Tennessee Aquarium (copies of these can be obtained by writing the author). The exhibit was filled and flushed with freshwater three times prior to the final fill and salt loading. The water was allowed to stand at least 48 hours after each fill to allow for lime leaching. Following this, a period of two weeks was budgeted for general lifesupport system start-up to allow for training, instruction, adjustments, and corrections as needed. Biological seeding of the filters and beds occurred about 25 days prior to the introductions and were completed with a large water change a few days prior. Lime leaching during the seeding required minor pH adjustments and did not present a biological problem, however, did require considerable time to clean calcium deposit off of the exhibit surfaces and acrylic.

The new Discovery Reef Aquarium incorporates several recent technological developments including an artificial wave maker. Buried inside a display of manmade coral is the exhibit's underwater surge machine whose nominal three foot diameter plunger cycles up and down six feet displacing enough water to recreate the effect of the surging ocean against the reef's wall. Designed by Separation Engineering, Inc., the surge plunger provides an extra touch of realism to the exhibit by moving flexible corals and animals back and forth. Exhibit lighting consists of fifteen 400 watt metal halide lamps. Use of theatrical housings and lenses allows for broadcasting or pinpointing. The lights are strategically located approximately 10' above the water's surface and are set to beam at an angle. This along with the surface rippling caused by the plunger, generates a very effective and naturalistic look from the visitor's point of view. All lighting is placed on a master timer which sequences a gradual "lighting up and down" each day. A florescent lamp positioned a distance from the exhibit provides a faint "moon effect" nightlight. Gallery illumination is also provided at gallery seating areas and stairs by low voltage linear step lights. At night, metal halide lamps flood an architectonic representation of a lighthouse above the new building's main entrance and multicolored fiber optic lighting rides along the top of a large blue wave at the building's side elevation. Other light fixtures were selected that reinforce the aquarium's nautical theme.

As of this writing, The Columbus Zoo has experienced no leaks or significant cracking in the main exhibit walls or viewing windows. The water is contained within the exhibit by a thick Polybrid (Liberty Protective Coatings, Inc.) elastomeric polyurethane coating over special corrosion resistant concrete walls. The public wall of the tank allows nearly continuous viewing by use of 5 1/2" thick clear acrylic panels each 16' long by up to 10' high (Reynolds Polymer Tech.) The panels were curved to follow the undulating curvature of the tank's 64' long viewing wall. A massive concrete catwalk structure rings the top of the tank to resist the force of water and to hold the tank walls securely in place. This structure has the added benefit of allowing husbandry staff access all around the tank for feeding, maintenance, diver assistance, etc. A unique feature of the catwalk is that a portion of it is constructed of fiberglass reinforced plastic grating that can be lifted up to allow diver access to a concealed flume. The diver can step down into the 3' deep water filled flume where equipment can be put on, the diver can acclimate, and then slide out into the exhibit from a hidden entryway.

Limited husbandry staff time dedicated to lifesupport system maintenance dictated a system designed to be simple but efficient.

The Zoo elected not to use any automated system components so that husbandry staff would stay in touch with the operations and not become reliant on automatic functions. Water exits the main exhibit via two large surface skimmers located in the back corners of the exhibit. The skimmers empty into two large weirs whose volume was designed to be large enough so that they would not run dry during the alternating water levels created by the surge. The weirs are drained by a common manifold which feeds the main pumps (25 hsp Fybroc). Only one pump is engaged at any time yielding a flow rate of approximately 1,300 gpm, while the second, which is connected to an 200 kw emergency generator as are other critical building functions, serves as a back-up. Accounting for displacement from the exhibitry, exhibit water turnover is estimated at a rate of approximately once per hour. The pump moves the water through a series of four 3' diameter x 8' long horizontal rapid sand filters (Stark). The water exits the sand filters where it is then directed one of three ways. The majority of the water (approx. 82%) is sent to a large degassing tower located in the ceiling area. After degassing, the water falls into and is collected in a large common head box. The remaining flow is sent to a heat exchanger sideloop (approx. 3%) or to the ozone sideloop (approx. 15%). The ozone sideloop consists of two large fiberglass vessels (approximately 23' high, 3' diameter, 1,050 gallon) connected in sequence. Counter current mixing method is utilized with mixing time at approximately 5.25 minutes. Water enters the first vessel where the ozone gas is mixed with the water and then follows a similar path through the second vessel where the water is mixed with compressed air to degas any residual ozone. Water exits the degas vessel and passes through a second packed degas column before finally exiting into the common head box. Ozone gas is produced by a standard 2 lb corona discharge generator located in a separate mechanical room (OREC). The generator is fed from a oil free air compressor and monitored by a high range ozone monitor (PCI). The ozone mixing only occurs during the periods which husbandry staff are on duty and is shut down otherwise. The heat exchanger sideloop also returns to the common headbox. After the building opened, this headbox was loaded with biopacking materials to provide a bacterial bed to serve as a final residual ozone sink should any remain. The common headbox elevation is higher than that of the main exhibit water level, so water is gravity fed back to the exhibit floor where it re-enters the exhibit through a reverse flow biological filter bed. An autodialer alarm system monitors several system parameters including water levels, temperature, water flow, power, etc., and will signal malfunction via telephone and audible alarm. Artificial sea water is prepared in and discharged from an 10,000 gallon underground vault. Two 5,000 gallon underground vaults can be used for backwash recovery or for artificial sea water mixing. High nutrient levels found in the backwash effluent has made its recovery an undesirable process. The husbandry staff is currently experimenting with the use of large algal turf scrubbers as a means of removing these nutrient levels.

The final construction of the 12,000 square foot facility was achieved under the construction budget at $2.96 million. The construction schedule was accelerated by dividing the work into an early bid package containing the site work and exterior walls and a second bid package containing all other building work. General contractors for the project were Berry & Miller Construction, Inc., and Central Ohio Building Company, respectively. Thanks to the cooperative spirit that prevailed at the job site between the owner, architect, and contractors, Discovery Reef opened as scheduled just prior to the 1993 Memorial Day weekend to crowds of 30,000+ visitors. Since opening, the facility has proven its worth as a multi-use building. Besides its value as a very popular visitor attraction, the building has been used extensively by the Zoo's education department for various activities, as well as, for after hours events including meetings, catered evening social events and even a couple of wedding receptions. Careful planning, teamwork and effective cost and project management, the functional value of Discovery Reef as a year round multi-purpose educational public facility has made this project a very successful venture for the Columbus Zoo.

Contractors Mentioned

URS Consultants
33 North High St
Columbus OH 43215-3076
(614) 464-4500

Separation Engineering, Inc.
931-A S. Andreasen Dr.
Escondido, CA 92029-1915
(619) 489-0101

Liberty Protective Coatings
1423 W. Ormsby Ave.
Louisville KY. 40210
(502) 634-9458

The Larson Company
6701 S. Midvale Park Rd.
Tucson, AZ 85746
(602) 294-3900

Kramer, Chin, Mayo
1917 First Ave.
Seattle, WA 98101-1027
(206) 443-5300

Berry & Miller Construction, Inc.
50 Hill Rd. S.
Pickerington, OH 43147
(614) 833-4800

Central Ohio Building
3756 Agler Rd
P.O. Box 30728
Columbus, OH 43230-0728
(614) 475-6392

Reynolds Polymer Technology
311 E. Alton
Santa Ana, CA 92707
(800) 433-9293

OREC
4953 W. Missouri Ave
Phoenix, AZ 85301
(602) 931-7332

Questions and comments can be directed to: Doug Warmolts, Columbus Zoo, P.O. Box 400, Powell, OH 43065-0400.

SPECIES LIST FOR NEW AQUARIUM EXHIBIT

LATIN NAME	COMMON NAME
Pomacanthus imperator	emperor angelfish
Arusetta asfur	arabian angelfish
Pomacanthus annularis	blue ring angelfish
Pomacanthus maculosus	blue moon angelfish
Pomacanthus semicirculatus	semicircle angelfish
Centropyge acanthops	flameback pygmy angelfish
Centropyge loriculus	flame pygmy angelfish
Centropyge eibli	Eibli's pygmy angelfish
Heniochus acuminatus	banded pennantfish
Heniochus monocerus	pennantfish
Hemitaurichthys zoster	black pyramid butterflyfish
Chaetodon auriga	threadfin butterflyfish
Chaetodon lunula	racoon butterflyfish
Chaetodon falcula	double saddleback butterflyfish
Caetodon ehippium	saddleback butterflyfish
Platax orbicularis	batfish
Scatophagus argus	scat
Monodactylus sebae	mono
Alectis ciliaris (Selene volmer)	lookdown
Gnathanodon speciosus	barred jack
Anthias spamipinnis	coral fish
Aetobatus narinari	eagle ray
Taeniura lymma	bluedot stingray
Dasyatis sephen	Pacific stingray (?)
Chrysiptera cyanea	blue devil damsefish
Chrysiptera hemicyanea	yellowtail damselfish
Chromis viridis	green chromis
Cirritops fasciatus	red banded hawkfish
Oxycirrhitus typus	longnose hawkfish
Lienardella fasciata	harlequin tuskfish
Coris formosa	African red wrasse
Coris aygula	twinspot wrasse
Balistoides conspicillum	clown triggerfish
Naso lituratus	lipstick tang
Paracanthurus hepatus	yellowtail blue tang
Acanthurus leucosternon	powder blue tang
Zebrasoma xanthurus	purple tang
Acanthurus triostegus	convict tang
Sphaeramia orbicularis	orbic cardinal
Chelonia mydas	green sea turtle
Comphosus varius	green blue wrasse
Labroides dimidiatus	cleaner wrasse
Chromis bicolor	bicolor chromis
Mugil sp.	mullet species
Heterodontus francisi	horn shark
Chiloscyllium punctatum	brown banded bamboo shark
Chiloscyllium plagiosum	white-spotted bamboo shark

AUSTRALIAN LUNGFISH SPAWN AGAIN IN CLEVELAND

Richard M. Segedi

Cleveland Metroparks Zoo

On Thursday, October 20th, Dan Moreno noticed some small gelatinous spheres the size of frog's eggs floating in the filter of the Australian lungfish exhibit. Not daring to hope that they were lungfish eggs, he at first thought that they were floating bits of snail egg masses. Aquarist Nick Zarlinga, who was standing nearby, noticed more of these same spheres on the surface of the filter gravel. He then went around and looked into the exhibit and found still more among the rock work. By that time Moreno knew that they were indeed Australian lungfish eggs.

Over the next week we separated several batches of eggs and placed them in a number of reserve tanks and containers, some with gentian violet, some with methylene blue, some with malachite green and some with nothing at all. We also separated and preserved a few eggs in formalin each day for future reference. We soon found that there was no development; in fact the eggs were slowly deteriorating. We took some of the unpreserved eggs as well as all of the preserved ones to Dr. Andrew White, Professor of Biology and a limnologist at John Carrol University and he concurred that there were no signs of development.

This incident is significant in that there has been no laying of lungfish eggs here between an instance in 1968, a year and some months after receiving our original pair directly from Australia, and the present. In all of those 26 years, we had only our two original lungfish together in the system. In February of this year, however, we obtained two more Australian lungfish from the Mystic Marinelife Aquarium on breeding loan and placed them in the system. These two new individuals have never been sexed and had been at Mystic since 1976 with no spawning activity ever noted. We have reason to believe that the individual that laid the eggs was our original female who, in 1968 produced a fertile batch from which 8 hatchlings emerged. However, it is striking that after so long a hiatus, the introduction of the two new individuals was followed by the recent spawning in just over 7 months. It is our hope that there will be more breeding activity among these four individuals in the near future.

Version 3 of the Aquapro Computer Program

Nearly two years in development, version 3 of Aquapro is finally ready for distribution. As with past versions, this software is available free of charge to North American zoos and public aquariums. Aquapro 3 requires a 286 or higher MS-DOS Windows computer with a hard drive, mouse, and a 3.5" HD floppy drive.

This new version contains the Maslen fish-mass estimator program, refined search features for all the databases, and basic care information for more than 4000 species of aquatic animals and plants.

To receive a copy, send your request on your organization's letterhead along with two formatted 3.5" HD floppy disks and a heavy self-addressed, stamped envelope (with $1.44 postage attached) to:

Jay Hemdal
Curator of Fishes
The Toledo Zoo
P.O. Box 4010
Toledo, OH 43609

AN INEXPENSIVE HEAT EXCHANGER

Jason Watters, Ed Comer

Marine World Africa USA

When we decided that we would like to acquire some animals that we felt would find our 54 degree cold water system a little chilly and our 76 degree tropical system a bit toasty, we found ourselves in a bit of a dilemma. It happened that the budget for the project was incapable of affording a chiller to maintain the small system at the desired 60 degrees and there was no point in relying on ambient temperature to remain steady year round. We did, however, have a constant supply of 54 degree water. Knowing that the ambient temperature in the area where the system was being constructed rarely dropped below the mid-fifties, we realized that we would rarely have to heat the tank if we could just keep it chilled during the times when air temperature would tend to warm it.

I was able to talk our electrician out of a fairly nice thermostat and managed to find, cleanup, and fit an old ball. valve actuator onto a 3/4 inch valve. We now had the controls, all we needed was a heat exchanger(wasn't that the original problem?). We toyed with the idea of coiling a length of stainless or titanium tubing through which cold water would run and placing this in a chamber that would be flooded with warmer, temperate system water whenever the thermostat deemed it necessary. None of the local machine shops thought they were capable of fabricating the coil for us however, and were unwilling to pay for the tubing if they ruined it in the attempt. We did, however, have a bare wall night next to the system in question. Why not make a long, wall mounted heat exchanger. A similar idea that I had seen used by many homebrewers had proven to be quite efficient, so with a few modifications, our heat exchanger was born.

Our heat exchanger is composed of two 95 inch runs of 1/2" 316 stainless steel housed within 1 1/2" pvc. Cold water runs through the pvc while water from the temperate system runs in the opposite direction through the stainless. A very simple design, see diagram, the heat exchanger has been capable of holding the temperature of the 300 gallon system steady at temperatures as low as 56 degrees while ambient temperature was around 73 degrees. Presently, the system is being held at 65 degrees and has been kept at this temperature during, the hottest of summer when ambient temperature has risen dramatically.