DRUM *and* CROAKER

A Highly Irregular Journal for the Public Aquarist

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Cover Art: Spot prawn gyotaku by Bruce Koike.

DRUM AND CROAKER 40 YEARS AGO
(Excerpts from the 1971 issue)

Richard M. Segedi

BOOK REVIEW

Fish and Invertebrate Culture Water Management in Closed Systems, by Stephen H. Spotte

There are copious amounts of shallow, popular literature and extremely deep, scientific data on the subjects of aquatic animal maintenance and water chemistry. Here at last is a collation of practical information, presented in an organized fashion and backed up with sufficient references. As so well put by Dr. James W. Atz, "Now, fish culturists experimental biologists, and amateur and professional aquarists have a firm bridge between their fishkeeping activities and the diverse chemical, biological, limnological, and oceanographic literature that bears on them."

SIGNS AND SENSE

George B. Rabb, Chicago Zoological Park

The stereotypy prevailing in labeling exhibits in zoos and aquaria seems to stem from traditions of the natural history cabinet. The focus is taxonomic, with perhaps a few words on common questions such as maximum size, food, etc. The ordinary format used for signs is a familiar and monotonous one: bold common name, followed by scientific name, and tiny text or standard map. Casual observation indicated that the usual signs at Brookfield Zoo were not making much of an impact, although the public may ask for the ordinary information because that is what they're accustomed to receive in zoos. Experiments using different textual material, especially in regard to titles, indicate that the public does respond positively to different approaches. Subjects of new signs included the animals, their behavior, features of their artificial habitat, zoo husbandry and conservation practices, etc. We recommend concentrated effort on all aspects of sign production: typographical format, content, vocabulary, length, color, shape, placement.

OF MANATEES AND OTHER THINGS

Earl S. Herald, Steinhart Aquarium

Florida being the only place in the world other than an aquarium where one can observe manatees in clear water, the writer together with a photographic buddy, Jerry Meyer, descended upon west Florida's Crystal River to film the manatees. The clutter of photographers was amazing -- Philippe Cousteau with an eleven-man film crew, including an old friend Ron Church, the head cameraman; Marlin Perkins and his group in an adjacent area -- it almost looked as though there would not be enough manatees to go around. Mother Nature stepped into the picture by decrying warm weather so that the manatees would not come into the 72° spring, but remained downriver in the *Anachris* beds which provided impossibly turbid water.

JAPANESE AQUARIUM TOUR

Earl S. Herald

The proposed professional aquarist tour of some 25 leading Japanese aquariums has been postponed until fall 1972. The University of California Extension Division under Dr. Nathan Cohen has tentatively agreed to organize the tour which will require about 20 days. A day of technical sessions is planned for Tokyo with participation of Japanese and other aquarists. The costs will be kept as low as possible and will range somewhere between $1,200 and $1,500 based on San Francisco departure. In many ways the Japanese aquarists are ahead of us, so this is a good opportunity to find out what they are doing.

Drawing by Craig Phillips

A VERSATILE ALGAE ANCHORING SYSTEM

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Decorating an exhibit can be one of the more challenging yet rewarding aspects of aquarium keeping. To reproduce the most natural environment in our tanks, a source of fresh algae is very helpful. While collecting, I always keep an eye open for rocks with a lush covering of various algae; however, placing these rocks in the exhibit in a natural way can be quite challenging. Another approach is to take detached algae and wedge it into nooks and crannies amongst the rocks of the display. While this method can work in the short term, typically algae will become dislodged over time due to the rummaging of the animals in the exhibit, or simply from daily maintenance. One method for larger, more robust algae like the Southern Sea Palm (*Eisenia arborea*) is to tie the holdfast to a rock that can then be positioned in the exhibit. This works until the holdfast can re-attach; in the meantime, twine used to attach the holdfast may be visible to the public. You are also limited in placement options by where the rock itself best fits in the exhibit.

A technique I have used in the past for displaying *Eisenia,* as well as other algae, involves substituting a torpedo sinker for a rock when anchoring algae amongst the substrate. The use of a sinker enables the anchor to slide between rocks, allowing the holdfast to sit on the surface of the substrate. Using this method, I have been able to easily pull the palm kelp on a frequent basis to trim any senescent blades, rinse off any detritus buildup, and scrub off any epiphytic growth. Because of this forgiving anchoring system, the algae is not limited to an area where the substrate 'fits'. I am able to reposition the plant in different spots or orientations until I find a look I am comfortable with. Re-arranging the scenery in such a way also gives the display a fresh look and encourages foraging behaviors in the exhibit animals as they explore their changing surroundings.

Materials

- 3 oz torpedo sinker found in any fishing store. Different sizes of sinkers can be substituted depending on algae and system requirements. I find the tapered design of the torpedo works best for this application.
- # 6 tarred nylon three strand seine twine (black)
- Black plasti-dip/ tool dip
- Large paper clip bent into a hook
- Sail needle
- Algae

Anchor preparation

1. Attach a length of twine to a sinker and hang from a large paper clip bent into a hook.
2. Find an area where anchors can be hung to dry after dipping in tool-dip. Dip sinker and hang up to dry. Be sure eyelet is clear during drying so that the dip does not skim over

and close the eye. Black tool-dip allows for a high level of camouflage for the anchors. The black blends into the shadows among the rocks allowing more versatility in placement without having to worry about something artificial being seen amidst the substrate. The tool-dip has the added bonus of coating the brass eye of the sinker, eliminating the possibility of deterioration of the brass eye during long-term immersion.

3. Hang anchor to dry, administer a second coat for more durability (Fig. 1).

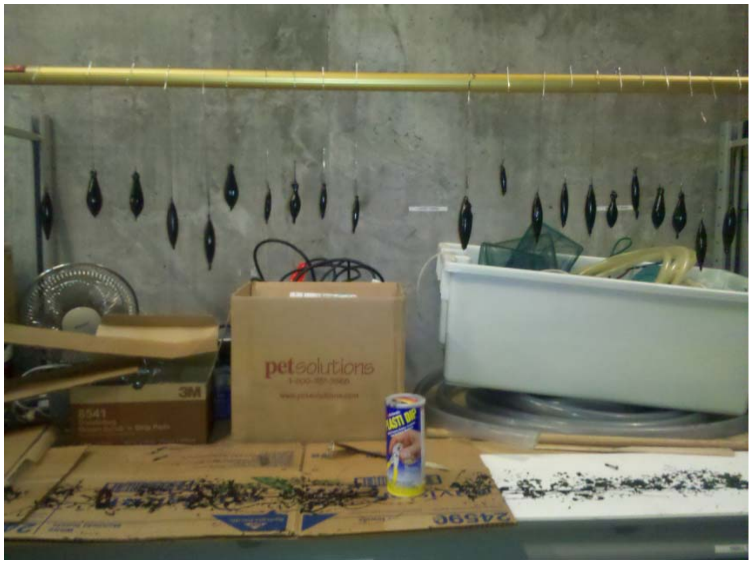

Fig. 1: A variety of anchor sizes. I find it useful to make anchors in large batches to insure the right anchor is at hand for whatever alga needs I may run across.

Anchor Attachment to Algae

In this instance, I describe the attachment of the anchor system to *Eisenia arborea*, a short stalky subtidal sea palm with a holdfast approximately 4-5 inches in diameter found in our local waters (Fig. 2).

1. Cut a 2 foot piece of #6 three-strand tarred twine and unravel into three individual strands. This will give you three black threads that are extremely durable and very low-profile, allowing them to more easily blend in with the holdfast or algae mass.
2. Tie one end of a single strand of tarred thread to the eye of an anchor, leaving approximately six inches to finish off any knots. Thread long end through sail needle and work needle through holdfast near base of the stalk. Pass over and back through holdfast and tie to tag-line on anchor. Repeat until you are satisfied everything is going to stay in place. I find that because this particular line is so rugged and the holdfast so dense that one or two passes is sufficient to attach the anchor to the plant. The anchor should be able to freely pivot beneath the central mass of the holdfast. Trim any excess thread (Fig. 3).

Fig. 2: Holdfast, coated torpedo sinker, sail needle and single strand of #6 tarred seine twine in preparation for anchoring.

Placement of Algae in Display

Find a nook amid the rocks of the substrate where the anchor will nestle and provide the holdfast with a natural look. If upon looking at the exhibit from the display side you find the algae looks unnatural or hides other areas of the exhibit you want to have on display, simply grab the algae with a pair of tongs and move it to another location.

With frequent pulling of the *Eisenia* plants for cleaning and pruning, I have had individual plants on display for months. Trimming off any senescent material and lightly scrubbing the blades with an acrylic pad mimics the surge these plants would normally be exposed to in the rough conditions this species of kelp is normally found in. I have had much new blade growth as well as holdfast growth engulfing the anchors in a relatively small 300 gallon display with no artificial surge beyond conventional water jets. With the kelp attached directly to the substrate or a rock, I would not be able to easily remove it from the exhibit on a regular basis for this necessary attention. As a result, the kelp tends to deteriorate at a much faster rate.

When selecting substrate for display, I try to find pieces of rock which have been perforated by rock-boring clams or similar organisms or naturally contain numerous fissures in the rock itself. I find that smaller torpedo sinkers slide nicely into these holes. At the California Science Center we will be having backdrops created for several of our focus tanks. The inclusion of holes camouflaged as rock-boring clam holes or similar nooks and crannies in the back drop will allow for the use of this anchoring technique to more easily decorate the insert.

If there are any questions regarding this technique, please feel free to contact me.
Good luck!

Fig. 3: Finished anchor. Note anchor is snug to the holdfast and dangles freely beneath. For algae that occur more in bunches or have a very small hold-fast area, simply bunch up the algae and tie the line around the base of the clump.

MANAGING A SOUTH AMERICAN PASSERINE POPULATION IN THE LARGEST SPHERICAL RAINFOREST EXHIBIT IN THE WORLD

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The rainforest exhibit at the California Academy of Sciences is a free-flight, mixed-species display that is a 90-foot diameter glass sphere. The space includes one large open-topped pool with live fish, two planted beds, an elevator system, and a ramp that extends from level one to level three. The birds are exhibited along with live butterflies, so the exhibit itself is a USDA containment room. The birds have access to nearly everything within the glass containment walls.

Picture 1: Exterior view of Rainforest Exhibit

Picture 2: View from upper level

The exhibit is staffed by two aviculturists, three herpetologists, two horticulturists, three aquarists, and two generalists. Each level boasts numerous terrariums and fish tanks that are serviced daily before opening to the public.

We have overcome a myriad of challenges since opening this exhibit in September of 2008. In addition to the stresses of introducing a variety of species at one time, biologists had to contend with a 360-degree glass sphere, feeding free-flying birds and butterflies, and navigating a 100,000 gallon open-topped freshwater fish tank that houses bird-eating fish such as pacu, arawana, and arapaima.

Introductions

Introducing a number of animals all at once is always a dicey proposition. The stress of introducing approximately 35 individuals of different species was only compounded by having to release them into a giant glass sphere. This posed the problem of how to minimize injuries from birds flying into the glass accidently. Many ideas were considered – decals, spray 'snow', etc. We finally formalized a plan whereby the entire exterior of the structure would be covered in shade cloth. This was a huge undertaking, as the circumference of the sphere is formidable. We also hung shade cloth in front of the galleries on each level in order to prevent birds from getting 'lost' or 'stuck' when they were first released. Consequently, there were no deaths from glass strikes on initial release.

Species were housed according to size/compatibility, and howdied in the exhibit for a few days before the doors were left open allowing the birds to venture out at will. The smaller species (honeycreepers, euphonias, paradise tanagers, opal-rumped tanagers) were released first to give them a chance to establish territory and find safe roosting areas, followed by the larger more aggressive species (silver-beaked tanager, red-shouldered tanager, turquoise tanager, saffron finch). The last species to be given access was the blue ground dove.

As expected, there were multitudes of dynamics between individuals. We lost a few birds to male/male aggression fairly quickly. The silver-beaked tanager, and surprisingly, the violaceous euphonia males killed the other resident males of their species within days upon release. We also noted immediate aggression between the lone saffron finch and the yellow-green grosbeaks. This aggression escalated when five more saffron finches from another facility were introduced at a later date. Unfortunately, when the flock increased from one individual to six, the grosbeaks were targeted directly and had to be removed from the exhibit. We assume color was the instigating factor.

Picture 3: *Caryothraustes Canadensis*

Picture 4: *Tangara chilensis*

Picture 5: *Claravis pretiosa*

The only ground species that was introduced into the original population was the blue ground dove. This species tends to fly 'up' when startled, and after losing a significant number of individuals to trauma induced injuries we returned the remainder of the population to the breeder. Due to limited planted exhibit space, we chose not to pursue introducing any additional ground species.

Feeding

We had to devise a system that would permit not only the passerines access to food on multiple strata, but also the butterflies. Free standing feeders in the ground level planters were inaccessible to the public and fairly easy for biologists and birds to access. More challenging however, was how to have food and nectar available on the two upper levels. There is not floor space on these levels that the public does not have access to, therefore we created feeders that would hang from the railings over open space. The feeders were thin metal rods with plate-sized metal rings on the end. These were welded to the railings on levels 2 and 3, and were able to swing out and back for access. A locking pin holds them in place so that they remain stationary until a biologist changes the plates.

Picture 6: Hanging feeder, Madagascar Level

Picture 7: Hanging feeder, Madagascar Level

Our original idea was to be able to set the plates inside the rings. The drawback to this arrangement was that the plates occasionally got knocked out and fell. It didn't take us long to figure out that plates and nectar containers would have to be plastic. After trying a few different prototypes, we found that a plate with a locking mechanism was the best bet, so we changed the holder to a flat disc with a central hole. The food plates have central plastic pins that lock them onto the discs with a quick twist. We also found an ideal length for the metal rod – long enough that the public could not lean over and reach the food, but short enough that stability was not compromised.

Picture 8: Feeder and locking dish

Picture 9: Feeder and locking dish

The birds are fed a fresh fruit and vegetable mixture along with Mazuri pellet and softbill. Insects are offered daily - mealworms, phoenix worms or waxworms. As the exhibit is now inhabited by nuisance ants that seem to be attracted to crickets, these insects are no longer on the menu. Nectar is offered in the morning, oranges in the afternoon. The butterflies quickly 'learned' where the nectar stations were. Finding a container that would hold an appropriate amount of nectar, but was not so deep that the butterflies would drown was an ongoing concern for the biologists. After many different designs we finally concocted one that holds a sufficient amount of liquid and offers the butterflies an 'island' to set upon so that they don't get stuck. We now use plastic condiment cups and plastic petri dishes. The petri dishes float on top of the nectar and provide the butterflies an opportunity to perch as they're feeding. Multiple cups at each station cut down on bird/bird and bird/butterfly altercations.


Picture 10: Nectar feeders


Picture 11: *Heliconius sp.*


Picture 12: *Coereba flaveola*

Inherent Challenges in Mixed Species Exhibits

There are always issues with interspecies interactions in mixed exhibits. The rainforest exhibit boasts a 100,000 gallon open-topped tank filled with predatory Amazonian species such as arawana, pacu, and arapaima. These species strike at low flying birds or butterflies from the water's surface. After the initial bird population stabilized and became habituated to the space, we found that most of the 'fish-related fatalities' were the result of altercations between individual birds. Birds that are being chased or are entangled with one another cannot adequately maneuver close to the water's surface.

The birds are not just prey however, they are also predators. Approximately 100 butterflies are released into the rainforest every week. Even with supplemental insects offered daily, meals on wings are hard to resist. While enriching for the birds, butterflies can be pricey.

We found butterfly decimation most notably occurred when our larger species of birds (silver-beaked tanagers specifically) had chicks to feed. We now coordinate with our horticulturists so that they can adjust the number of butterflies released when we have parents with chicks.


Picture 13: *Ara macao, Ara ararauna*


Picture 14: View of Flooded Forest from tunnel


Picture 15: *Osteoglossum bicirrhosum*


Picture 16: *Colossoma macropomum*


Picture 17: *Ramphocelus carbo* eating *Phoebis philea*

Capture and Restraint

A permanent catch cage was set up in order for us to catch birds that needed to be banded or medically evaluated. This is a stationary cage on the ground level and is a primary feed station. Insects are offered in this cage only to encourage frequent visits. We selected a free-standing cage with a large, side-opening door. The capture method is relatively straight forward; a thin rope tied to the door and a biologist lurking behind a plant. We also use this cage to howdy birds being introduced into the collection. Birds are restrained using paper lunch sacs and clothespins. The paper lunch sacs are optimal, as they do not need to be laundered and can serve as fecal repositories for the hospital. Being able to record weights and band numbers directly on the bags also cuts down on confusion and record keeping when dealing with multiple animals.

Picture 18: Catch cage, Borneo Level. *Can you find the biologist?*

Nesting and Breeding

We were surprised, yet pleased to discover that birds were nest building and breeding just weeks after the initial introduction to the exhibit. The birds took advantage of all possible space, even when proximately to the public seemed daunting.

The exhibit contains free-standing terrariums that house a variety of herptiles and invertebrates. The herpetologists were chagrined to discover that birds are thieves, and were stealing all the materials designated for their terrariums to build nests. Changes were made to some terrarium tops after finding birds whose toes and feet were caught up in fibrous straps. The horticulturists were chagrined to discover that birds are thieves, and were stealing all the materials designated for the living walls. These moss-filled living walls were so popular with the euphonias that they forewent the gathering and transport, and just moved in directly. Fabricated cup and dome nests were provided and used intermittently by a few species, but no matter the amount of nesting material supplied, the material of choice appears to be tissue and paper towels discarded by the public.

Picture 19: *Ramphocelus carbo* incubating in palm next to public walkway

Picture 20: *Euphonia violacea*

Picture 21: *Kristensis natolii*

The silver-beaked tanagers were the first species to successfully raise offspring. So successful in fact, biologists frequently pull the male off exhibit in order to manage the population. The other species that have produced viable offspring thus far are the blue-gray tanagers and the bananaquits. All other species have exhibited nest building behavior and eggs have been laid by the euphonias and the opal-rumped, turquoise, red-shouldered, and paradise tanagers.

One of the more remarkable behaviors that the biologists noted was the interspecies female/female cooperation when there were no males of the species present. After losing the resident male opal-rumped tanager and two out of three female turquoise tanagers, the remaining opal-rumped and turquoise females proceeded to build a nest together. After completing the nest, they each laid eggs in it and took turns incubating. Sometimes they sat on the nest at the same time, one slightly on top of the other. We've also seen somewhat of a similar behavior

Picture 22: *Ramphocelus carbo* nest in palm

Picture 23: *Tachyphonus phoenicius* incubating in planter

between the three female paradise tanagers. There have been 'shared' nests in which more than one individual has laid her eggs. These eggs were subsequently incubated by the nest's 'owner.' Interestingly, when males of their species were introduced back into the collection, it seemed to take these 'co-op' females more time to accept the male than those females that did not participate.

Chicks and Fledging

Fledging is precarious no matter what the environment, and the rainforest exhibit is full of challenges for young birds. Some of the dangers are obvious – a giant, open-topped tank filled with carnivorous fish is difficult for even the savviest adults to navigate. Some of the dangers were not as self-evident, and both biologists and fledglings had to learn the hard way. One fledgling was lost to a school of cichlids in a gallery tank– only then was it discovered that the installation of the tank's lid was overlooked during the flurry of opening. Many youngsters found themselves stuck in areas that their parents had a hard time reaching, such as buckets and bins that were stored back of house, etc. As parents became more habituated to the space these incidents decreased. Biologists noted that the younger birds were no longer leaving the forested area of the exhibit.

Some issues arose even before chicks were ready to fledge. From a necropsy done on a deceased blue-gray tanager chick, it was revealed that the parents were feeding it inappropriate materials. Biologists pulled the next clutch with the intention of hand rearing the offspring. Although the hand rearing attempt was successful for one of the chicks, the reintroduction into the collection was not.

The resident blue-gray pair immediately attacked the juvenile, likely deeming it a threat to their territory. In general, reintroduction of any young individuals that have been pulled off exhibit for an extended period of time has not been effective. Resident adults of the same species continue to assess both their own and others' offspring as threats upon reintroduction. It is interesting to note that adults with established hierarchies do not have the same issue, even when pulled off exhibit for medical procedures that have taken upwards of four weeks.

Picture 24: Hand-reared *Thraupis episcopus*

Picture 25: *Ramphocelus carbo,* 4 days

Fostering

Biologists noted that when the adult female yellow-green grosbeak was in the exhibit with the rest of the population, she was extremely interested in the silver-beaked tanager fledglings and appeared to be feeding them. Our attempts at fostering chicks to her off exhibit were not successful due to the fact that even though she would elicit feeding responses from them and 'go through the motions' of feeding, she did not actually bring food to them. When re-released onto exhibit she became so possessive over the chicks, the parents were unable to feed their own offspring and biologists had to pull her off exhibit again.

Picture 26: *Ramphocelus carbo*, 2 days

Picture 27: Fostered *Ramphocelus carbo* "Charlie"

Attempts at fostering silver-beaked chicks to silver-beaked females other than the biological mother were unsuccessful as well. These females showed no interest whatsoever when chicks were offered for fostering off exhibit.

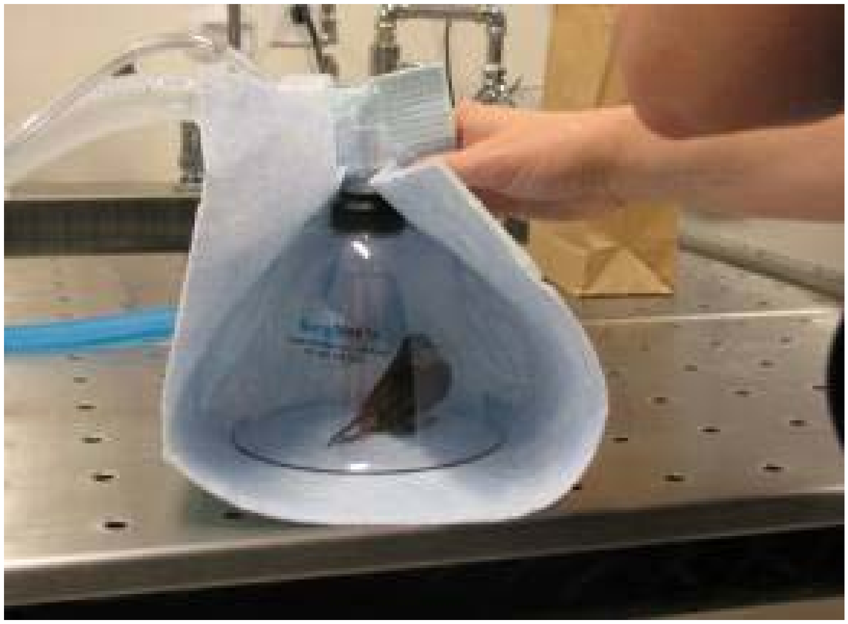
We've seen the female red-legged honeycreepers exhibit a feeding behavior with the silver-beaked tanager fledglings as well, but it is unclear whether or not they are actually delivering any nutrients to the youngsters.

Picture 28: *Cyanerpes cyaneus, Ramphocelus carbo*

Disease Process

Limited space for any population is never ideal, and finding quarantine space in an aquarium is always a challenge. We were tasked with quarantining upwards of 40 birds in preparation for the opening of the new building. The majority of the initial population was wild-caught birds purchased from a broker in Florida. We experienced some mortalities in quarantine that upon necropsy were attributed to salmonella. The violaceous euphonias were the species hit hardest by this during quarantine. After being released into the exhibit, there were some individuals that succumbed to complications caused by salmonella as well. It should be noted that these individuals were all part of the initial population exposed during quarantine. Once the birds were released and their proximity to each other was increased, we did not experience any mortalities due to transmission between newly introduced animals or offspring. Because salmonella is a zoonotic, our veterinary staff took a pro-active approach contacting public health. It was determined that the risk of the public contracting the disease while walking through the exhibit was comparable to walking in any outdoor environment.

After introducing four adult bananaquits into the population a year after opening, one of the pairs started successfully breeding on exhibit. Biologists noted that the fledglings would do well initially, and then start showing symptoms of neurological compromise at approximately 5-6 weeks of age. Necropsy results revealed that the cause of death was atoxoplasma. Though known to be present in the resident population, the bananaquit fledglings are the only ones thus far to suffer mortalities as a result. Biologists coordinated with the hospital to start medicating the population *in situ* with sulfachlorpyridazine one-two days prior to the next clutch of bananquit chicks hatching. We found this 'pre-medicating' increased survival rate during the fledging period.



Picture 29: *Tangara cayana,* anesthesia using an induction chamber

Picture 30: *Tangara cayana* positioned for diagnostic x-rays. Diagnosed with abscess in breast muscle, cultured salmonella

Picture 31: *Coereba flaveola* with fledgling

Our veterinary staff continues to be vigilant about testing animals in quarantine, on exhibit, and post-mortem. Specimens are tested for salmonella, coccidia, atoxoplasma, chlamydia, and micobacteria. Tissue samples are banked at all necropsies. Histopathology and PCR probes are performed whenever cause of death is not immediately apparent.

For the Future

We have reached our primary goal of establishing and maintaining a healthy population of passerines in an extremely complex exhibit space, and our goals for the future will focus primarily on breeding. With that in mind, we have begun the process of creating a more 'chick friendly' exhibit space. This includes obtaining a large nylon net that can be installed over the tank during fledging or introductions in hopes of decreasing subsequent 'fish-related fatalities.' We also plan to install flight cages off exhibit. These would allow us to encourage off exhibit breeding, as well as maintaining flight endurance for off exhibit birds that will eventually be re-released onto exhibit.

Species list

Saffron Finch (*Sicalis flaveola)*

Yellow-green Grosbeak (*Caryothraustes canadensis)*

Violaceous Euphonia (*Euphonia violacea*)

Paradise Tanager (*Tangara chilensis*)

Silver-beaked Tanager (*Ramphocelus carbo*)

Red-shouldered Tanager (*Tachyphonus phoenicius*)

Opal-rumped Tanager (*Tangara velia*)

Turquoise Tanager (*Tangara mexicana*)

Rufous-crowned Tanager (*Tangara cayana*)

Black-faced Dacnis (*Dacnis lineata*)

Blue Dacnis (*Dacnis cayana*)

Yellow-legged Honeycreeper (*Cyanerpes caeruleus*)

Red-legged Honeycreeper (*Cyanerpes cyaneus*)

Bananaquit (*Coereba flaveola*)

Blue-gray Tanager (*Thraupis episcopus*)

Blue Ground Dove (*Claravis pretiosa*)

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POST-MORTEM ANALYSIS OF CUTTLEBONES PROVIDES CRITICAL INSIGHT INTO THE NATURAL HISTORY OF CAPTIVE CUTTLEFISH, *Sepia*

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Abstract

Cephalopods do not possess many hard structures that persist after death: nautilus shells wash up on shore, beaks are collected from predator stomachs, and cuttlebones remain after food processing. As a result, cephalopods (the ammonites and nautiloids withstanding) are not easily distinguishable in the fossil record. However, these hard structures may provide evidence of life history behaviors and strategies of both extinct and extant cephalopods. The proper interpretation of cuttlebones would provide further insight into the behaviors of both wild and captive cuttlefish. This additional information could be applied to conservation policies for wild cuttlefish and improved husbandry methods for captive cuttlefish while also aiding evolutionary studies. The data presented in this study demonstrate several correlations between cuttlebone features, i.e. length and age, length and growth rate, that can be recorded on post-mortem analysis. Rather than set out to definitely prove or disprove applicable hypotheses, the current data sets intend to show the research method applied and present *probable* hypotheses, from the current data, with the caveat that additional data is needed to provide significant conclusions.

Introduction

Various species of cuttlefish are maintained in captivity in both aquarium and research systems. Cuttlefish, *Sepia* sp., have been utilized in research studies for decades (Forsythe *et al.,* 1994; Boal, 1999; Forsythe *et al*., 2002; Barord *et al*., 2010) and are also popular as display animals at public aquariums; *Sepia officinalis*, *Sepia pharaonis* and *Sepia bandensis* being the most commonly displayed cuttlefish. The captive display of any cephalopod requires a strict adherence to water quality parameters (Oestmann, 1997) and system design. Cephalopods are sensitive to poor water quality conditions as a result of their porous microvillus epidermis and health may deteriorate in unsuitable conditions (Scimeca, 2006). The internal structures of cuttlefish, and all cephalopods, may deteriorate quickly after death so that crucial aspects of its anatomy are unreliable for assessment. The cuttlebone, therefore, may be the only account of past trauma (Feral, 1978) and the interpretation may lead to improved understanding of the group in captivity and wild habitats.

Cuttlebones perform a similar function as the chambered shell of the *Nautilus*, whereas the chambered shell regulates the buoyancy of *Nautilus*, so too does the cuttlebone for cuttlefish. These structures are unpressurized systems that do not significantly change in volume or buoyancy during depth changes (Denton and Gilpin-Brown, 1961) but these depth changes do require the cuttlebone and other chambered shells to withstand the hydrostatic pressure at increased depth (Denton and Gilpin-Brown, 1961; Ward and Boletzky, 1984). However, this buoyancy system is completely unchanged during vertical movements (Denton, 1974; Ward, 1987). The limitations of the chambered shells are one of the primary factors limiting range, in terms of maximum depth limits.

There have been several growth studies analyzing cuttlebones of both wild and captive cuttlefish to gain a better understanding of the relationship between age and the growth lamellae developed along the cuttlebone (Re and Narciso, 1994; Le Goff *et al*., 1998; Bettencourt and Guerra, 2001). These studies are not only important to improved husbandry practices, but may also be a practical way to collect vital fisheries data in the areas where cuttlefish are harvested (Bettencourt and Guerra, 1999; Turan and Yaglioglu, 2010). Cuttlebone morphology can be used to distinguish many species and may also be used to determine age, biomass (Almonacido-Rioseco *et al*., 2008), and even sex of the individual (Bello, 2001; Almonacido-Rioseco *et al*., 2008). Additionally, Bello and Paparella (2003) took one step further and analyzed scarring on wild *Sepia orbignyana* cuttlebones and what may be the cause. Ward and Boletzky (1984) noted dark colored septa along the cuttlebone during shell implosion trials in three species of cuttlefish. Cuttlebones have also been used as an indicator of ocean acidification. Gutowska, *et al*. (2008) determined that *S. officinalis* maintained and even improved calcification rate and body mass when exposed to increased concentrations of carbon dioxide, whereas many other calcifying invertebrates respond negatively to increased carbon dioxide (Fabry, *et al*., 2008). Cuttlebones are a good model for life history studies, as well as evolutionary based research, because of their abundance (Neige, 2006).

This ongoing study attempts to provide baseline data that can be used upon necropsy analysis of captive cuttlefish and perhaps a framework for the examination of wild cuttlebones for fisheries data. The life history of individual cuttlefish can be difficult to monitor in the wild leading to posited assumptions of cuttlebone interpretations. Ideally, captive cuttlefish are monitored on a daily basis and any stressors or occurrences can be observed and recorded, which can then be tracked back to the cuttlebone. Thus, assessments of cuttlebones of captive cuttlefish with their behaviors may then be used to interpret cuttlebone morphology of wild specimens.

Methodology

The initial cuttlebone dataset (N=10) was presented at the 21st Regional Aquatics Workshop and consists of *S. pharaonis* and *S. officinalis* data (Barord, 2007). The supplementary data sets (N=45) were obtained from several additional aquariums. The temperature and salinity of the systems was provided as well as the approximate age of the specimen if known. The cuttlebone length and number of growth lamellae were recorded for each cuttlebone, if applicable. The growth rate, defined as the number of days per lamellae deposition, was obtained by dividing the total number of growth lamellae into the age of the specimen.

Approximate age for several *S. officinalis* cuttlebones (N=26) was not known so these data do not reflect towards calculated growth rates though length and number of lamellae were still recorded and used in appropriate analysis. Some of the cuttlebones (N=2) were left out entirely because of poor condition; the growth lamellae were unreadable. All of the cuttlebones were analyzed in this same manner. Photographs were provided by the author from the most recent cuttlebones collected. The data was analyzed using both Microsoft Excel.

Results

Fifty three cuttlebones were analyzed in this study. A total of 34 cuttlebones from *S. officinalis* and 19 cuttlebones from *S. pharaonis* were obtained. The sex ratio of *S. officinalis* was 15.14.4 (M.F.U) and 12.7.0 for *S. pharaonis*. The average cuttlebone length of *S. officinalis* was 12.54 cm and 13.19 cm for *S. pharaonis*. The length and number of each growth lamellae were compared graphically for *S. officinalis* (Fig 1, 2, 3) and *S. pharaonis* (Fig 4, 5, 6). There appears to be on observable trend of increased cuttlebone lengths producing an increasing number of growth lamellae and although there are indeed notable oscillations along the graph, these oscillations may be averaged out and support a more reliable model for reference.

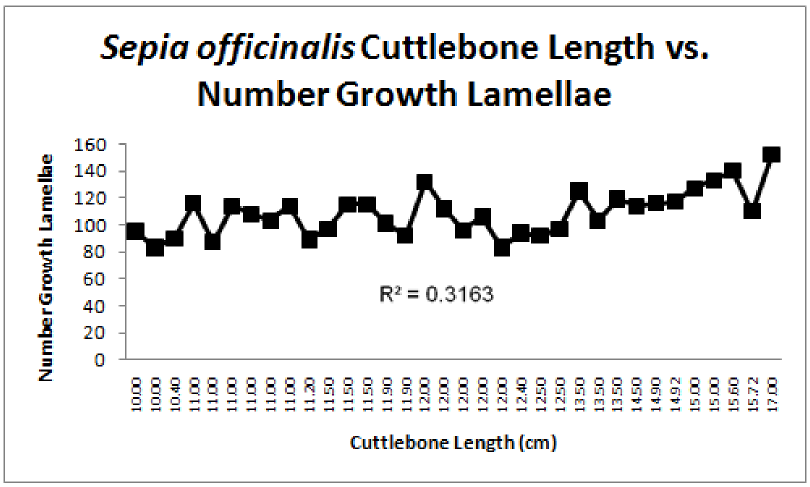

Figure 1. *Sepia officinalis* cuttlebone length (cm) per number of growth lamellae for males and females.

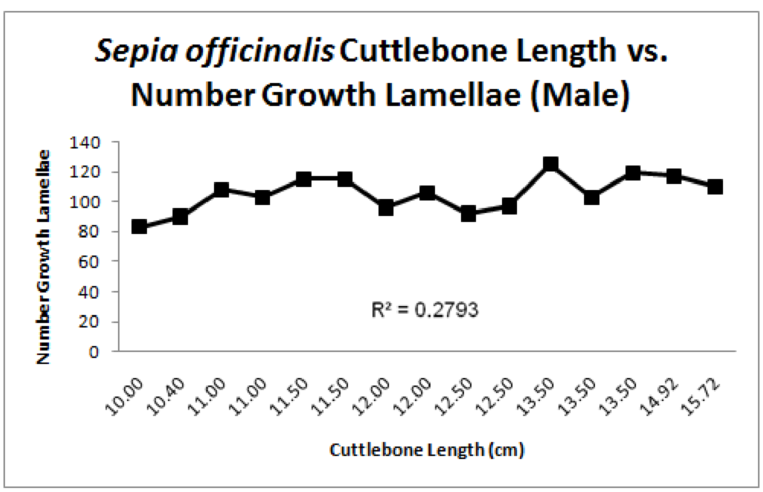

Figure 2. *Sepia officinalis* cuttlebone length (cm) per number of growth lamellae for males.

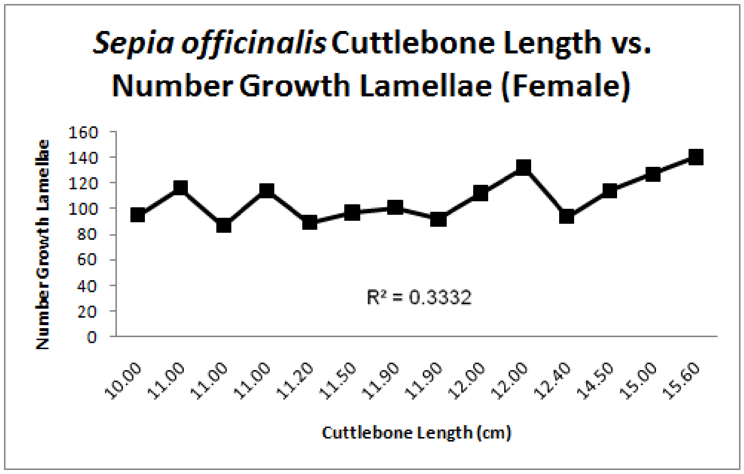

Figure 3. *Sepia officinalis* cuttlebone length (cm) per number of growth lamellae for females.

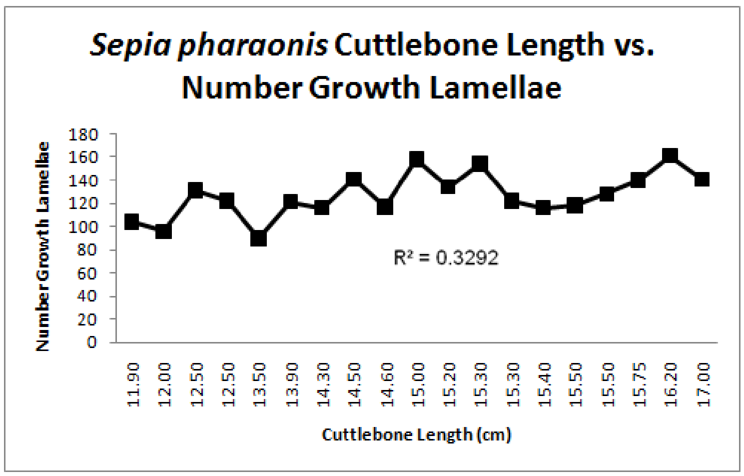

Figure 4. *Sepia pharaonis* cuttlebone length (cm) per number of growth lamellae for males and females.

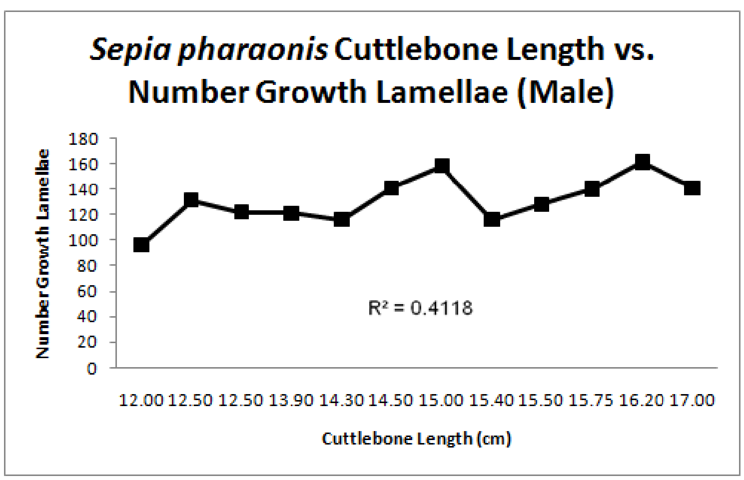

Figure 5. *Sepia pharaonis* cuttlebone length (cm) per number of growth lamellae for males.

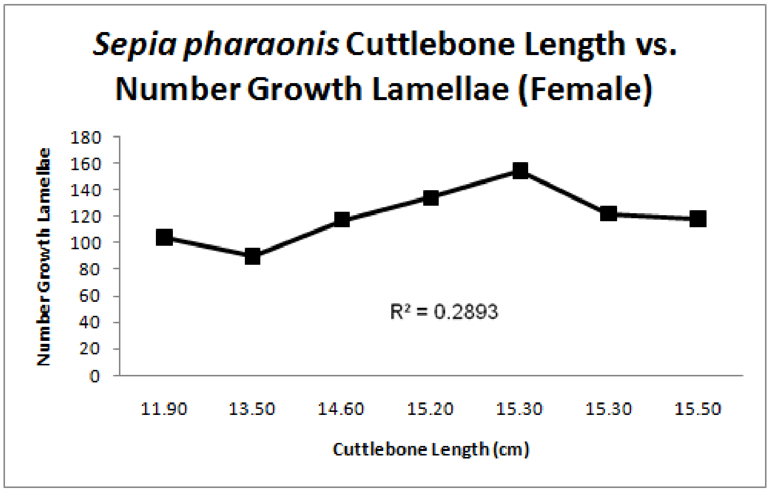

Figure 6. *Sepia pharaonis* cuttlebone length (cm) per number of growth lamellae for females.

Growth rates were calculated for only eight of the *S. officinalis* (due to unknown ages) and a total of 19 *S. pharaonis*. The average growth rate for *S. officinalis* was 2.04 d/lamellae and 1.80 d/lamellae for *S. pharaonis*. There were no significant differences of growth rates between males and females of each species. The growth lamellae counted on the ventral portion of the shell are observable in Figure 7.

Figure 7. Ventral side of a cuttlebone showing the deposited growth lamellae.

There were several morphological differences recorded among the different cuttlebones, most notably, the scarring along the ventral portion of the cuttlebone evident by black lines (Fig 8). The black lines were apparent on over 90% of the cuttlebones in this study and several of the cuttlebones, presumably in the same collection, showed similar scarring locations along the cuttlebone which may be evidence of trauma that affected the entire collection in the system at that time. Several of the cuttlebones show evidence of multiple scarring events along the cuttlebone, as shown in Figure 9. Beyond these 'normal' scarring occurrences, there are several

Figure 8. A cuttlebone showing scarring events along the ventral portion of the cuttlebone.

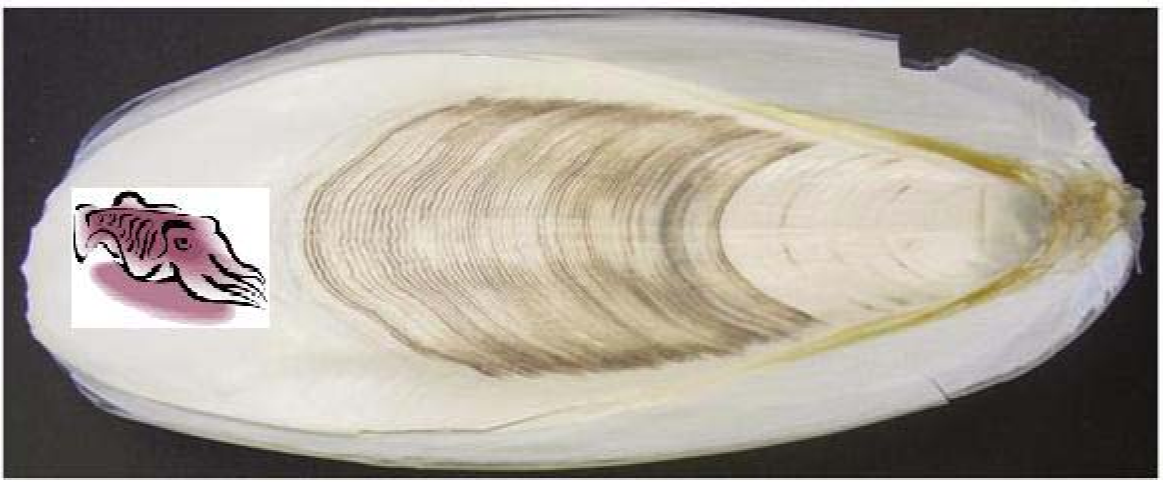

Figure 9. A cuttlebone showing several scarring lines.

Figure 10. Strange growth pattern of single cuttlebone on ventral side.

other abnormalities evident in the cuttlebones analyzed in these studies. Figure 10 shows one of these occurrences of abnormal calcification along the cuttlebone.

Discussion

Cuttlebones are abundant and may be the only means of assessing life history behaviors of cuttlefish during their lifetime. Reliable interpretations of cuttlebones rely on many important variables that must be known to infer accurate conclusions. Temperature may be the primary indicator of growth rates and life span, so recording the temperature of the system is vital during cuttlebone analysis. Many species have broad temperature ranges and can be maintained at different temperatures in captivity. For example, two individual cuttlefish raised in different temperatures may be the same age at death but cuttlebone lengths, lamellae, and calculated growth rates may be very different. If temperature is known in this case, then these differences may be more readily explained. The system temperatures were available for all of the cuttlebones in this study and the temperatures were consistent with accepted growth rates of the two species.

Overall, the number of growth lamellae increased in larger cuttlebones. Differences in calcification rates during the specimen's life time may explain several of the oscillations observable in some of the data points. This data type was presented to illustrate the possible correlations between different data that could be more readily defined with additional information. Cuttlefish hatchlings grow exponentially early in life and subsequently decrease with the animals' age. So, variation in the number of growth lamellae recorded among cuttlebones of similar lengths could be explained by temperature variation for definite time periods or other anomalies such as changes in food items. As stated previously, calcification rates of cuttlefish increase during exposure to higher levels of carbon dioxide so this data may explain abnormalities in wild cuttlefish in certain regions. Other aspects of captive conditions, such as stocking density, may also impact growth rates of cuttlefish.

Scarring has been noted in wild nautilus and was common in most of the cuttlebones in this study. Attributing these scarring events to root causes is nearly impossible for wild cuttlefish but because captive cuttlefish are monitored on a daily basis, it is possible to attribute captive scarring to stressors that were also recorded. For example, similar scarring locations along the cuttlebones of specimens maintained in the same system could be due to a spike in ammonia or nitrite levels if this spike was correlated to the scarring based upon age data and water quality records. It is difficult to definitively characterize this relationship, but based upon the data, it is a possible explanation.

Additional examples of stressors in captivity that may induce scarring include aggression, guest interaction, and competition. Reproductive behavior may also cause scarring along cuttlebones, although this form is defined as a natural stressor. Natural stressors must be recorded in some form during the animal's captive care so that it may be correlated to data obtained from the cuttlebone. Interpreting these types of results may allow more effective husbandry practices to be initiated and may include improved filtration to further reduce spikes in toxic water quality parameters and also differing stocking densities that may improve behaviors and reduce stressors. There is the additional question of whether or not these scars impede the animal in any way. Scars ascribed to reproductive behavior may show that husbandry conditions were conducive to normal behaviors which would further support those practices being successful.

It is interesting that cuttlefish and *Nautilus* both possess buoyancy regulating chambered shells and both of these hard structures show similar black lines during its growth. While the root causes of the black lines in both structures may be different between the species, the mechanism that causes the black lines to occur may be similar and provide additional information to the husbandry of both species. Further research into this relationship is needed to determine if there are any correlations between cuttlebone scarring events and the shell of chambered nautilus.

Though this study expounds upon the original data, there must be additional data collected to formulate reliable models for which to base assumptions. An ongoing database of cuttlebone information would provide information that can be accessed during necropsy investigation and has been developed in cooperation with The Octopus News Magazine Online. The development of this database may serve the fisheries industry as well by providing large datasets for comparison, even though they are from captive specimens. Increased data may provide more reliable and effective conservation initiatives and regulations to ensure the sustainability of species of interest for fisheries. This interplay between data from wild and captive cuttlefish would further the conservational message of many aquariums and groups by applying data collected under captive conditions to *in situ* conservation, thereby influencing public policy and opinion. Future research will expound upon these results in both sample size and analysis methods.

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CAPTIVE CALAMARI: THE CHALLENGE OF KEEPING CAPTIVE SQUID

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What is a Squid?

Squid are cephalopods - molluscan animals that are accomplished swimmers with fins on either side of their torpedo-shaped body. They have eight short suckered arms and two long tentacles used for catching prey, usually small fish, crustaceans or other squid. Like many other cephalopods such as cuttlefish or octopuses, squid have chromatophores in their skin that they use to produce color patterns for camouflage, communication with other squid and to other species.

Some squid are "true" squid, members of the order Teuthida. Other squid-like cephalopods are also called squid, and some of these can be kept in aquariums as well. Relatives to true squids such as sepiolids and cuttlefish are often easier to care for.

Squid are powerful swimmers capable of rapid acceleration. They tend to react swiftly to changes in their environment. These traits make squid very difficult to keep in captivity. They swim by a combination of forcing water jets out their funnel or swimming with their two fins. The water jets are used for fast escapes from potential predators. Fish, marine mammals and marine birds, all vertebrates also with good senses and mobility are the major predators of squid. To detect and avoid predators, squid have well-developed senses such as large eyes to watch for predators. Their defense against predators includes jetting away, inking and changing color.

Squid live in schools. This offers additional protection against predation, however squid are cannibalistic! No wonder squid are the "nervous nellies" of the cephalopod world. They may jet into aquarium walls with their posterior ends and run the very strong risk of injury. Squid frequently develop "butt burn," an injury on their posterior end that often gets infected with ambient bacteria and can become a white lesion. When disturbed, they can even jet violently out of tanks without lids.

As a whole, squid are extremely difficult to rear and raise in captivity and few species have ever been raised from eggs. Most squid have planktonic paralarvae (hatchlings) that swim and feed in the near the surface of the ocean. During that time the paralarvae feed on a diversity of tiny crustaceans and fish larvae that are also part of the plankton. These conditions are very difficult to duplicate in the lab or aquarium. In addition, most adult squid are prone to hitting the sides of their enclosure violently when they are disturbed by something such as the room lights turning on. There are a few exceptions to these guidelines and these are the squid that are more suited for captivity.

In general to keep squid in captivity: 1) get the biggest tank possible to give the squid plenty of room to swim and decrease the chances that they encounter a wall. Squid are typically kept in 1000 gallon systems or larger. 2) Line the sides of the tank with something soft, such as plastic tarps, so that when the squid jet and hit the sides they hit something soft. 3) Cover the top of the tank with a lid (mesh screen or plastic sheeting on a PVC frame) to keep squid from jetting out 4) reduce/eliminate rapid environmental changes – lights turning on suddenly, banging on the tank, rapid movements above or around the tanks.

Generally only large public aquariums and research institutions can keep squid, and even then the number of species of true squid that have been kept in captivity is small. Most species of octopuses and cuttlefish are much easier to keep in captivity than squid.

Giant Squid

Recently the media and the internet were all agog over the first photographs on video and capture of a giant squid (*Architeuthis dux*). The Japanese research team, led by Tsunemi Kubodera, captured the images and video south of Tokyo. The giant squid is the world's largest invertebrate and can get over 50 feet (17 meters)long and weigh over a ton (900 kg). The researchers caught the squid on a hook and line using a special lure and bait, fishing about 3000 feet deep (1000 meters). The animal caught was a female "just" 25 feet long (eight meters). It is amazing that seeing such a large animal alive in nature has only recently been accomplished. Giant squid are a symbol for how much we still don't know about the open ocean and deep-sea marine life.

Although a giant squid might thusly be caught alive, the obstacles to keeping a giant squid are tremendous and are most likely insurmountable. The squid pulled to the surface from depth is likely already dying due to the temperature and pressure changes.

A public aquarium director was depicted in the novel and movie of Peter Benchley's *Beast*, a tale of a crusty old fisherman, a fervent aquarium director, and a giant squid somewhat larger than life. In the story, a giant squid 50 feet (17 meters) long is caught and kept alive in a coastal lagoon, prior to transfer to a public aquarium. It turns out this is just a baby and the mother squid comes to save it.

A popular adage says "If it can be imagined, it can be achieved." Maybe Peter Benchley can imagine a giant squid in captivity, but there are enormous obstacles and challenges to overcome before doing this. The technology has not been developed yet to catch a live adult giant squid unharmed, bring it up thousands of feet (more than 300 meters) to the surface into warmer water and greatly reduced pressure that they are not used to living in, transfer it unharmed to shipboard and transport it to shore into a very large aquarium. Even designing and building a pressurized aquarium large enough of the proper design to keep it alive is presently beyond us. Like most squid the giant squid would probably be blinded by our daylight since it lives in the depths so it would have to be kept in the dark and not be disturbed because it would jet into the walls of any such enclosure, damaging itself.

Dr. Steve O'Shea and others recently discovered that baby giant squid live in more accessible surface waters. Catching very young giant squid in the plankton is an interesting strategy. One of us was a Smithsonian intern in the early 1990's and worked on catching baby cephalopods out of the plankton with the goal of raising them in captivity. The main challenge is that traditional plankton nets damage the plankton, they get abraded against the side of the net and are concentrated with other plankton, many of which sting or have spines. Planktonic cephalopods in the best health are very difficult to raise and require live crustacean food and damaged specimens will be even more challenging. If future scientists could someday locate eggs of giant squids or figure out a way to catch planktonic squid without damaging them (light traps, blue water dives with jars), they could start with specimens in the best health.

Jumbo Squid

In recent times yard-long (one meter) jumbo squid (also called Humboldt squid: *Dosidicus gigas*) have been making incursions up the west coast of America as they are carried northward by swirls of warm water moving north due to El Niño, possibly global warming or overfishing of their predators. They normally live in the Sea of Cortez southward to Chile in water from the surface down to a thousand feet deep (333 m) or more. They are ferocious predators that mostly feed on fish but are not above munching one of their own that is injured or dying.

Because of their ferocity, jumbo squid are known as the "red devils" ("los diablos rojos") by artisanal fishers in the Sea of Cortez. The squid catch fish with their two long tentacles which lash out, capture a fish, pull it in to be grasped by the eight arms, and then chewed to tiny bits with their formidable pointed beak inside the mouth. Each suction cup on the arms is aided by a sucker ring of hard chitin (like our fingernail material) armed with sharp teeth. Thus each sucker has the ability to eat into flesh such as a fish or humans. These squid travel in small schools known as shoals and when attacking a prey item they seem to go into a feeding frenzy, where they try to bite and eat anything in the area, including observing scuba divers, hence their bad reputation.

Due to their movement northward on the American west coast, they are much easier to obtain than giant squid but keeping them alive will still be an incredible challenge, and raising them is seemingly impossible at this time. Twenty years ago an aquarium director asked one of us what it would take to keep and display these red devils. He answered: $20 million: $10 million for R & D and to get them there alive and $10 million for the facility. Nowadays that figure would probably be multiplied by at least 10. However, we are making inroads into their aquarium husbandry. The Aquarium of the Pacific, Monterey Bay Aquarium and the Oregon Coast Aquarium have caught these, kept them alive long enough for transfer back to an aquarium, and kept them alive for several days in their existing tanks. To date no one has attempted to raise them in captivity, nor have any egg masses, paralarvae, or juveniles been found north of the Sea of Cortez.

Photo of a jumbo squid on the Oregon Coast. Photo by Keith Chandler, Seaside Aquarium

Smaller Squid

With smaller squid it is much easier to keep them in tanks that are relatively large compared to their size, this helps reduce collisions with the sides. These smaller inshore squid have all been raised in captivity, mostly by the National Resource Center for Cephalopods in the 1980s: the opalescent squid, sometimes known as the California market squid (*Loligo opalescens)*, longfin inshore squid (*Loligo pealei*) and the slender inshore squid (*Loligo plei*). Rearing and keeping them presented a distinct challenge even for the dedicated public aquarists and researchers with large tanks and access to live food. These squid were raised and kept in large circular tanks with soft sides, kept in the dark and minimally disturbed to minimize their banging into the walls of the tank. In addition the walls had a black and white pattern so the squid could see them. The water flow pattern helped keep them away from the sides and up off the bottom. These, and all other squid that have been successfully reared, were fed tiny crustaceans as first food, animals such as copepods, or mysid shrimp. Brine shrimp (adults and nauplii) are a much less effective food and are not recommended.

These squid, and most others, have a one to two year life cycle, depending on the water temperature. Compared to us they have a short life span. Squid lay eggs in finger-shaped gelatinous egg capsules in flower-like clusters on the bottom. Many female squid females lay eggs together. There's no such thing as "safe sex" for squid; males die shortly after mating and females die after a brief period of laying eggs. Thus there is no parental care of either eggs or hatchlings. Eggs usually hatch in one to two months, depending on the water temperature.

The Seattle Aquarium has kept adult opalescent squid, catching them with jigs using hook and line methods for squid that are drawn to lights on piers in the wintertime. These were fed krill and small frozen herring, fed individually with the food offered on a thin feeding stick made of PVC welding rod. The adults soon mated and laid eggs, and hence died of old age shortly thereafter following about a month in captivity. They were kept in large rectangular tanks about 5000 gallons (20,000 liters) with suitable fish.

Photo of opalescent squid. Seattle Aquarium

Two other true squid offer better potential for survival and reproduction in captivity but are still probably limited to large public aquariums or research institutions. These are the brief squid (*Loliguncula brevis*) and the Caribbean reef squid (*Sepioteuthis sepioidea*).

Most cephalopods are sensitive to environmental conditions like salinity. There are no freshwater cephalopods and few species can survive in brackish water. The brief squid, *Lolliguncula brevis*, lives in inlets and estuaries, from the north coast of South America to the Gulf of Mexico and up the eastern US. They survive in lower salinities and a wide range of temperatures and dissolved oxygen levels. A study conducted in the Chesapeake Bay found *L. brevis* in bottom-water salinities (17.9 to 35.0‰), bottom-water temperatures (8.1 to 29.6°C) and bottom-water dissolved oxygen levels (1.9 to 14.6 mg O2 l-1).

Brief squid are small, up to 8 inches (20 cm) long, and somewhat transparent. They have a small fin at the end of their mantle. Brief squid are typically collected using bottom trawls at 30-45 feet (10-15 m) deep. Trawls are an effective way to catch squid in highly productive low visibility estuary waters, but this collection method can damage the delicate skin of squid. Those that are not too damaged can be kept in captivity. This species is lot more tolerant of environmental changes than most cephalopods.

Caribbean reef squid (*Sepioteuthis sepioidea*) are found in the clear warm waters of the greater Caribbean. This coastal squid has large fins and is often confused with cuttlefish. This likeness to cuttlefish is doubly noted in the scientific name as “sepio” refers to *Sepia*, the genus of cuttlefish. Caribbean reef squid can be collected by hand which greatly minimizes abrasion to their skin. In Bermuda I one of us worked with teams of volunteers to herd the squid into a stationary seine net. A hand net was then used to transfer the squid into a container for transportation back to the lab. With this method, the squid were never taken out of the water.

Caribbean Reef Squid readily eat live silversides in the wild and in the lab. They also consume small crustaceans. We observed one eat a mantis shrimp (stomatopod) in Bonaire. Although others have reported that this species is not cannibalistic, we have observed cannibalism in both the wild and in the lab. These squid are capable of launching themselves out of the water and definitely need to be kept in covered tanks.

Along with Dr. Jennifer Mather and others, we have spent over a thousand hours watching these squid in Bermuda and Bonaire. The Discovery Channel special “Tentacles” features our work on visual communication of these squid. Our colleague Dr. Ruth Byrne led the development of identifying individual squid based on their unique dot pattern. This non-invasive method does not alter behavior. James and colleagues recently demonstrated that the ink of conspecifics of these squid acts as an alarm signal.

Bobtail squid and pygmy squid

These small squid-like creatures have the word “squid” in their common name but are not true squid (order Teuthida). Bobtail squid are sepiolids, cephalopods more related to cuttlefish than squid. Pygmy squid are also listed as sepiolids by the Integrated Taxonomic Information System (ITIS) although their familial location is in doubt. Because of both their small size and more mellow nature, sepiolids, cuttlefish and octopuses are relatively much easier than true squid

Note snorkeling observers above these reef squid at Bonaire. Photo by James B. Wood.

to keep in captivity. Hobbyists that want to display, keep, observe and reproduce "squid" will have a much greater chance of success with sepiolids.

Several species of bobtail squid are potentially good aquarium animals: the stubby squid (*Rossia pacifica*) of the northeastern Pacific coast and the bobtail squid of Hawaii and the tropical western Pacific. The species in Hawaii is *Euprymna scolopes* and the ones in the tropics are *E. tasmanica*, *E. hyllebergi*, and *E. morsei*. There are also numerous species of these engaging animals in the Mediterranean. Stubby squid are about two inches (5 cm) long at maturity and the others about one inch (2.5 cm).

These "squid" are mostly are mostly nocturnal (active at night) and they bury themselves under sand during the day, with only their two large eyes peering out, watching for predators. They have an interesting behavior where they throw sand on their backs to bury themselves. They live one to two years and females lay large single eggs in a cluster of 25-50, all about the size of a little fingernail (one cm). Eggs of tropical species take about a month to hatch and stubby squid in colder water (50^0F, 10^0 C) take up to six months. Adults need live shrimp up to their own size to feed on, and hatchlings eat small crustaceans such as mysids, or amphipods. They can be occasionally be bought from and shipped by local suppliers: see the "Sources of Live Cephalopods" on the internet Cephalopod Page run by one of us (JBW) and also check out the forum on TONMO.com. Soft sides on tanks are much less important for these species but a chiller is needed to keep stubby squid below 50^0 F (10^0 C).

A stubby squid of the Pacific Northwest. Photo by Leo Shaw, Seattle Aquarium.

Pygmy squid (*Idiosepius*, several species) are another group that could make good aquarium animals if they were available. There are several species in the tropical western Pacific. These only get one inch (2.5 cm) long and only live for two or three months so they deserve their common name. They live in sea grass where they attach to the blades with an adhesive organ on their backs and feed on small crustaceans. If a potential predator comes along the squid releases a substance that instantly dissolves the glue so it can jet away to safety. Pygmy squid have not been reared in captivity yet but when the technology for doing this is resolved, they should be good for public and private aquariums alike.

Pygmy squid have an adhesive sucker on their back to hold onto seagrass or other vegetation. Photo by James B. Wood.

Summary

Cephalopods can be challenging to keep in captivity and this is especially true for squid. Collecting and transporting them is a challenge, as is providing large, low stress soft sided aquariums. Only a few species of squid have been successfully raised in captivity. However, squid are incredibly interesting animals. They are the most powerful swimmers of the cephalopods and many species use complex patters on their skin to communicate with other squid and other species. It is an exciting time to study squid as the first photographs and video documentation of a live giant squid have just been recorded. Perhaps similar breakthroughs will occur in keeping captive squid. In the mean time, relatives of squid such as cuttlefish and sepiolids are much easier to keep in captivity.

Selected References:

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Mather, J.A, Anderson, R.C. & Wood, J.B 2010. Octopus – the Ocean's Intelligent Invertebrate. Timber Press (Portland, OR).

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BOOK REVIEW

Octopus

The Ocean's Intelligent Invertebrate

Jennifer A. Mather, Roland C. Anderson, and James B. Wood

Hardcover, 208 pages, 38 plates. 2010 Timber Press, Inc.
List Price: $25.95 USD, Amazon.com price: $17.13 USD (28 Oct 2010)

Review by: Jay Hemdal, Curator of Fishes and Invertebrates, The Toledo Zoo

This book, written by a team of three well-known aquatic scientists, covers the fascinating topic of octopuses like none before it. It is organized into eleven sections, starting with egg development, through reproduction and senescence, and ending with a discussion of other Cephalopods. The book also includes a comprehensive introduction to octopus biology and concludes with a postscript covering their captive husbandry. Eleven pages of references are available if additional information is needed about any topic cited in the book.

The approach used in writing a book with three authors worked very well; they used the term "we" unless the text came from a specific author, then they used that person's name. The writing style was seamless – a difficult accomplishment with multiple authors working on a project like this.

Over two dozen sidebars (identified by an octopus silhouette at the start of each section) are used throughout to highlight a given section of the book, usually through a personal anecdote from one of the authors.

The authors' adherence to personal observations and documented data eliminates the hyperbole that sometimes is seen in books about octopuses. They even delve into the origins of the story many of us have heard, that the octopus that leaves its aquarium at night, travels to an adjacent tank, eats some of the fish, and returns home. They report that the first recorded instance of this story comes from Henry Lee at the Brighton Aquarium in 1875. The authors conclude that, "Various versions of this story still permeate popular culture as urban myths." Indeed, many public aquariums have had the same story erroneously attributed to their own facility.

Some statements could benefit from additional clarification. For example, "an octopus can resist a pull 100 times its body weight." It would be helpful to know the species involved and how many arms were used. Likewise for the statement that "octopus move one foot per second." Which species and under what conditions? I also question the text, "Mimic octopuses have proven impossible to keep in captivity…" having worked with this species, I've found their husbandry requirements to be relatively straightforward.

I did learn quite a bit from this book. I had never heard the phrase "deimatic display" (to confound predators using a visual display, often of false eyespots) or knew what octopus ink is comprised of (mostly mucus, melanin and an irritating substance, tyrosinase).

This is an important book for public aquarists interested in octopuses, and can serve as a ready resource for developing new exhibits and accompanying educational graphics. The fact that this book is so well written, informative and covers such a fascinating subject, makes it a genuine pleasure to review – I heartily recommend it to all aquarists, divers and naturalists.

From the Back Cover
"The octopus has terrified, mystified, and fascinated the world from ancient times. In this revealing, close-up account of the stranger-than-fiction life cycle, ingenious anatomy, remarkable personalities, and uncanny intelligence of the eight-armed mollusk-without-a-shell, three avid field researchers tell a tale that will forever change the way you look at a wondrous creature of the deep."

THE DATA DUMP PROJECT - AN AQUARIST'S "COOKBOOK"
☞"*Recipes" Wanted*☜

Pete Mohan, PJMohan@akronzoo.org

Director of Animal Operations, Akron Zoological Park, Akron Ohio

Drum and Croaker has always served as a place to share information, and in the age of listserves and texting, continues to offer a comprehensive and permanent snapshot of aquarium technology that these media cannot. Procedures preserved in the archived older issues have been helpful to those who otherwise are forced to "reinvent the wheel" every 5-10 years.

The purpose of this column is to generate short articles on specific "how to" topics that are likely to be helpful to others down the road. If you've answered the same question 10 times on a listserve, just put it here for posterity and simply reply next time with a link! The material need not be new. Fundamentals and basics are often lost because they are never put to "paper". Like the offering below, they are often superseded by time-saving technology. But sometimes situations demand that you go back to "old school" methods.

If you are a packrat like me, you've got a file cabinet or shelf of binders somewhere stuffed with napkin drawings, parts lists, old emails and Aquaticinfo posts. I'd like to encourage aquarists of all levels to dig deep and pull out some of the gems that you've filed away. Share with us your successes and the failures that led you there. Tell us a bit about the people and situations that provided inspiration. Who did early work on this topic?

To start the juices flowing I've pulled a tattered file folder out of the stack of old file boxes that shares my basement with spiders, the 'laundry monster', and my homebrew supplies. Let me know if this "data dump" is helpful and please send yours this way for the 2012 issue. I won't place a limit on these per issue.

GELATIN-BASED DIETS
DD-001

Commercially produced gelatin-bound foods are now a mainstay of public aquarium diets, and have been available in "just add water" formats for over 15 years. They have simplified the process of providing a balanced diet to fishes, and are particularly useful as a vehicle for delivering accurately dosed oral medications to sick or quarantined animals.

History

It might be a surprise that gel diets were not really a new or innovative concept when they came into wide use in the mid-1990s. One important thing did change: the new premixed products were convenient and avoided the sticky, smelly mess of working with packaged gelatin, fish meal and fish oil.

The first Drum and Croaker article on gelatin-based diets appeared over 40 years ago, after the formula had already been in use at the authors' facility, the National Fisheries Center and Aquarium, for a number of years (Peterson et al. 1968). The intent of the early diet was to provide balanced nutrition by combining commercial trout pellet meal with more palatable whole seafoods and additional dietary supplements. It was also immediately recognized as a drug-delivery method. Sciarra (1977) of the Mystic Marinelife Aquarium reported refinements in nutritional profiles and production. A detailed approach to manufacture and nutrition was then taken by Spotte et al. (1985), in a collaboration between Mystic and academia. In early 1988 I located this paper and it became my introduction to, and bible for, gelatin diets. I saw it as an opportunity to address observed nutritional problems in my collection, particularly poor color and fatty liver disease. I based my early recipes on their formula and continued to use variations for nearly 15 years. The change in the health and appearance of fishes that received this diet was palpable. But not many folks in the field embraced gel diets. They were both time-consuming, and as mentioned earlier, unpleasant to produce. Eventually animal diet manufacturers resolved these problems. I received my first sample of a new Mazuri® carnivore diet in 1994, and omnivore and herbivore formulas were introduced in 1997. I switched pretty quickly to the manufactured carnivore product, but continued to use my own herbivore and omnivore diets for after the herbivore product appeared, simply because of an "it ain't broke, so don't fix it" mentality. I initially found the consistency of my scratch-made product firmer and it crumbled less in water than the commercial mix. This was likely due to differences in the way the gelatin and water interacted. Slightly varying the amount and temperature of the water and dry mix was helpful in improving the consistency of the "instant" product.

<u>My Experiences with Gel Production – The Data Dump</u>

Spotte's Connecticut-based team used a customized vitamin mix in their diet and I used the same product. Through serendipity, it turned out that the manufacturer, ICN Nutritional Biochemicals, had relocated to an industrial park about a mile from our facilities at SeaWorld Ohio (see the original 1985 paper for formula details). I sourced both fish meal and herring oil directly through companies that manufactured fish pellets, or was referred to their suppliers. In general these specialized vendors were happy to help a public aquarist even though I was buying tiny amounts of product. I agreed to ship my fish oil provider the quart bottles to be used for packaging my order (I didn't really need - and couldn't afford - the usual 55-gallon drum that was offered).

I've provided some sample diets below. The first is a carnivore formula based on the same basic ratios of major ingredients used in Spotte et al. (1985). These diets were re-portioned so they were all based on starting with 2-3 one-pound packages of unflavored gelatin, which can be obtained through a food service supply company. We made batches that would fill large, shallow, plastic tubs to a depth of 3-4 inches. These tubs were each large enough to cover the wire shelves in a commercial refrigerator.

I often added additional vitamins and minerals to my diets in an attempt to match recommendations from texts on fish nutrition, or to address specific concerns. I'll avoid providing most of those here, as I cannot recall their specific origin. I always included potassium iodide and can report that incidences of goiter became very rare after starting gel feedings. It is unclear if the overall balanced diet or iodine was important there. Another additional supplement was Cromophyl-ORO®, a marigold extract used by poultry producers to increase yellow coloration. I purchased mine through Purina Mills®, but I'm unsure of current availability. There seem to be other similar products currently produced such as Oro Glo® that may contain similarly derived xanthophylls. They may need to be used at different "dosages" than what I specified for the Cromophyl-ORO®.

After initially producing a carnivore diet, I developed a fish-free herbivore version that I felt would be more appropriate for grazers. Natural sources of carotenoids were included (spinach and carrots) as well as the dry extract. Endive and spinach were the preferred leaf vegetables due to better nutritional profiles than other locally available produce. Due to the amount of liquid contained in fresh greens the water component of this diet was reduced. A blender became an important tool as the produce needed to be pureed.

After several years I created a third diet that was a hybrid between the first two, essentially an omnivore diet. This is the second recipe presented here. Our team found it difficult to separate herbivores and carnivores during feedings so a compromise was reached that seemed to please both the fish and those subsequently making fewer different batches of gel.

Color improved on fish fed these various gel diets, but I cannot say whether the benefit came from fresh veggie pigments, the powdered carotenoid supplements, or some combination of the two sources. The level of obesity of herbivores in community tanks also decreased when I switched to the omnivore formula provided below.

<u>My Original Carnivore Diet (closely based on Spotte et al. 1985)</u>

7400 ml	water
906 gm	gelatin (2 one-lb packages)
22.10 gm	vitamin mix
21.34 gm	choline
250 gm	NaCl or "Sea Salts" (to prevent buoyancy in seawater)
3234 gm	fish meal
258 ml	herring oil
7.92 gm	Roxanthin Red
0.024 gm	KI
≤120 gm	Cromophyl-ORO (up to 1% weight of other ingredients including water)
???	other vitamins and minerals as needed.

1) Heat 4,000 ml H_2O to a boil, turn off heat and add gelatin slowly while stirring continually with a random stirring pattern.
2) Place fish meal in plastic tub and add oil. Mix thoroughly until all meal is uniform in color (darkened by oil). Break up lumps with spoon and force oil into all meal.
3) Add all vitamin mix, choline, salt, KI, Cromophyl-ORO, etc. to meal/oil mixture and mix in thoroughly.

4) Add 3,400 ml H_2O to meal mix and stir thoroughly.
5) Add Roxanthin Red to gelatin solution after the latter has been thoroughly dissolved and the few remaining clumps of gel powder have been skimmed out. Mix thoroughly.
6) Cool the gelatin/Roxanthin Red mixture in an ice bath while stirring continuously. When average temperature of this mixture and the fish meal mixture is no less than 26°C combine the two and mix thoroughly and continually to prevent layering. When the mixture begins to thicken noticeably (just short of solidifying) cover the container and move to a refrigerator. Cut into blocks equivalent to daily total usage, individually wrap, and freeze within 24 hours.

My Omnivore Gel Diet

2½ heads	washed endive
2½ lbs	washed spinach
75 oz	thawed carrot juice (bought in cases of quarts and stored frozen)
125 gm	spirulina powder
6,850 ml	water (6,000 ml is to boil in a pot, 850 ml to mix with fish meal)
808.5 gm	fish meal
64.5 ml	herring oil
3 lbs	unflavored gelatin (3 one-lb packages)
33.15 gm	vitamins (mix excludes dextrose option)
32.01 gm	choline
350 gm	NaCl
0.036 gm	KI
11.88 gm	Roxanthin Red
30 gm	Cromophyl - ORO
???	other vitamins and minerals as needed.

1. Boil 6,000 ml water in a pot, remove from heat, and then slowly add the 3 pounds of gelatin until completely dissolved. Add Roxanthin Red, mix, and place the pot in an ice bath. Stir continuously while cooling (see step 4).
2. Meanwhile, combine 850 ml water, herring oil and fish meal in a tub. Stir together.
3. In a blender, combine endive, spinach, carrot juice and all the remaining "dry" ingredients. This will need to be done in batches with smaller blenders. When done blending, mix these pureed ingredients with the fish meal mixture.
4. Cool the dissolved gelatin mix in ice bath until average temperature of the cold blended vegetable/meal mixture and warm gelatin solution is no less than 26°C. Combine and stir frequently to avoid layering. When the batch begins to thicken noticeably (just short of solidifying) cover the container and move to a refrigerator. Cut into blocks equivalent to daily total usage, individually wrap, and freeze within 24 hours.

Gel Diet Manufacturing Tips

- Turn off the stove before adding gelatin to a pot of boiling water. Otherwise the gelatin at the bottom of the pot will burn if you stop stirring for even a moment.

- Avoid getting steam from the pot in the mouth of your gelatin bags as you slowly empty them. It will congeal there. Pour the powder from a height.
- A large sink makes a good ice bath for cooling pots of hot gelatin solution.
- When you are done, DO NOT do the dishes. Fill all pots that have gelatin residue with water and leave overnight, tossing in any similarly sticky utensils. The water will soften the residue making it easy to remove the next morning. Or spend all afternoon scraping – your choice ☺
- Keep your fish meal and oil in sealed containers in the freezer.
- Wear rubber gloves. Or smell for days. Take a shower before going out with friends.
- Frozen gel is actually fairly easy to cut with a knife. If you have pre-frozen larger blocks in a "daily use" size, chopping will go faster.

References

Peterson, E.J., R.C. Robinson and H. Willoughby. 1968. A meal-gelatin diet for aquarium fishes. Drum and Croaker 68(1): 21-25.

Sciarra, J. 1977* A gelatin diet for marine fishes. Drum and Croaker 17(1): 45-51 (*incomplete version previously printed in 1976 issue)

Spotte, S., P.E. Stake, P.M. Bubucis, and J. D. Buck. 1985. Alginate- and gelatin-bound foods for exhibit fishes. Zoo Biology 4: 33-48.

REGIONAL AQUATICS WORKSHOP

Virginia Aquarium 2011

General Information for the RAW 2011:

Host Institution: Virginia Aquarium & Marine Science Center

Where:

Sheraton Virginia Beach Oceanfront Hotel
3501 Atlantic Ave
Virginia Beach, VA 23451
757-425-9000
www.starwoodhotels.com/sheraton/property/overview/index.html?propertyID=814
REMEMBER TO MENTION RAW 2011 WHEN BOOKING!

When: May 3-6, 2011 (AZA TAG MEETINGS May 2, 2011)

Tentative **Schedule for the Week:**

TAGs, AQIG meetings	May 2
RAW First-Timer Mixer	May 2 (evening)
Life Support and Water Quality Session	May 3
Fee-based and Animal Interactive Programs Session	May 3
Fish Propagation 101	May 3
General Session	May 4-6 (morning)
VAQ Icebreaker	May 3 (evening)
Coastal Cruise	May 4 (evening)
Aquarist Olympics	May 6 (afternoon)

Budget:

Registration:

Before Feb 1st, 2011 (fee per person)
____$50 Public Aquarium or Non-profit affiliate
____$125 Commercial Affiliate

After Feb 1st, 2011 (fee per person)
____$85 Public Aquarium or Non-profit affiliate
____$150 Commercial Affiliate

Room Rates:
At Sheraton Virginia Beach Oceanfront:
$112 / night plus tax City View
$117/ night plus tax Partial Ocean View
$119/ night plus tax Ocean View

Airport Options:

Highway traffic in Southeastern Virginia/Hampton Roads area is unpredictable. Traffic jams and heavy congestion resulting in traffic slow-downs must be expected and considered when making travel arrangements.

Airport Name	**Drive Distance to Sheraton**
Norfolk International Airport (ORF)	20-30 minutes
Newport-News Williamsburg International Airport (PHF)	60-90 minutes
Richmond International Airport (RIC)	120-180 minutes

*Washington DC and Baltimore area airports are **NOT** recommended due to regular lengthy traffic delays and extreme highway congestion.*

Ground Transportation Options:

By Taxi *(Example from ORF to Hotel)*
Fee: 30 USD *(one way)*

By Rental Car *(Examples are from ORF)*

Avis Rent A Car	**Enterprise Rent A Car**
Beach Ford Car Rental	**Budget Car Rental**
Dollar Rent A Car	**Hertz Car Rental**

Car parking at Sheraton Oceanfront Hotel is complimentary (free valet is also available) and parking is right across the street from the Hotel.

RAW 2010 ABSTRACTS
"OmaRAW", Regional Aquatics Workshop, June 7 - 12
Omaha's Henry Doorly Zoo, Omaha, NE, USA

Abstracts compiled by conference organizers; edited by Pete Mohan (D&C Editor) to match the presentation schedule provided by Mitch Carl in October 2010.

[Where abstracts were not submitted to Drum and Croaker by the host, basic information is provided as available using the distributed program.]

Monday, June 7
Pre-RAW AZA Conservation Group Working Meetings

Freshwater Fishes TAG
Aquatic Invertebrate TAG
Coral Reef CAP
Marine Fishes TAG
Aquatic Interest Group (AQIG)

Tuesday, June 8, AM Session I
Life Support

Welcoming Addresses

Sponsor Presentation – Emperor Aquatics

Ultraviolet Disinfection Bio Security – Specification, Operation and Maintenance in a New Era

Adrian Megay
Emperor Aquatics

Case Study to Evaluate Novel Energy Efficiency Technology's Affects on Sustainable LSS

Greg Whittaker
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Moody Gardens

With increasing pressure to reduce operating costs AND improve guest experience, improvements in operating efficiency are the primary area to explore. Flux Drive mechanical Adjustable Speed Drive (ASD) technology has recently become available in production scale to aquarium life support systems. The first prototype installation to showcase the technology to the professional aquarium community occurred in April 2009 at the Aquatic Animal Life Support Operators (AALSO) symposium in Seattle. A second installation was done at the Houston Zoo in September 2009. Aggressive research and development offered the opportunity a larger model on a 50 HP marine aquarium system at Moody Gardens in February 2010. The primary purpose for the installation was to serve as an operational demonstration for the 2010 AALSO symposium hosted by Moody Gardens in May. Significant improvements in the design showcased in this third model include; scaled up magnetic components to allow higher horsepower torque transfer, 4-20 milliamp actuator control and double track pilot bearings. The installation timeline allowed for a full three months of real world operation on a functioning large scale LSS to track efficiency and power consumption data prior to the professional symposium. At the time of install, performance data was assembled for several torque transfer settings from fully engaged through approximately 27% torque slip, which allowed us to anticipate real power consumption values.

The preliminary data indicates a significant reduction in power consumption and improved operational control of LSS functionality. Indirect benefits include improved electric motor efficiency with a reduced operating temperature, reductions in alignment induced vibrations affecting both motor and pump bearings, and elimination of shock transfer both directions across the pump drive connection caused by motor start up and impellor impactions. At our pre-determined torque transfer setting, we are tracking a consistent 30% reduction in power consumption. Although power rates vary, and ultimately dictate actual savings, our anticipated savings on this single installation is between $5500 and $6000 for the first 12 months of operation.

Objective assessment of particulate filtration efficiency associated with this installation has not been determined, but subjectively, there have not been any observed detrimental effects. Following the AALSO symposium, a second phase of operational testing has been implemented to attempt to identify the optimum torque transfer setting to balance power consumption and filtration efficiency.

Dissolved Organic Carbon Testing in Seawater Using the UV254 Method

Matt Wandell
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California Academy of Sciences

Levels of Dissolved Organic Carbon (DOC) in saltwater aquariums are not frequently tested due primarily to the expense and time invested with standard methods. Here we present a simple and effective method for determining the DOC level in seawater by proxy using the UV254 method and a spectrometer.

Tuesday, June 8, AM Session II
Conservation and Education

Aquarium Collection Sustainability - Planning for the Future

Dennis A. Thoney, Ph.D
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Vancouver Aquarium

The Association of Zoos and Aquariums (AZA) has established two committees (one terrestrial oriented and one aquatic oriented) to address future sustainability in North American animal collections. The Aquatic Collection Sustainability Committee has written a white paper which outlines the different challenges faced by aquatic collections versus our terrestrial counterparts. The paper defines the issues and outlines actions that should be taken to ensure that aquatic collections will be viable and sustainable into the future. In general, public aquariums must ensure that animal collection practices are sustainable to conserve natural resources. They also must expand captive propagation by increasing efforts in research, development, and production. To meet these goals, the Aquatic Sustainability Committee is developing an Aquatic Sustainability Action Plan to address the conclusions of the white paper. Part of the Action Plan will be to develop a certified list of suppliers that AZA members will be strongly encouraged to use when acquiring animals.

Initiation of a North Texas Unionid Mussel Conservation Program at the Dallas Aquarium

Barrett Christie
Dallas Aquarium at Fairpark

Coral Restoration Efforts at the Florida Aquarium

Allan Marshall
amarshall@flaquarium.org
The Florida Aquarium

The Florida Aquarium's Center for Conservation and partners have pursued coral research and restoration initiatives for nearly a decade, beginning with the construction of The Coral Farm on the exhibit pathway in 2001 as part of the Florida Keys National Marine Sanctuary (FKNMS)'s "Reef Medic" program, serving as a repository for threatened or damaged Atlantic coral fragments. More recently, we have explored culture techniques for reef restoration, comparing culture success of closed and open systems with offshore culture. Results of seven species of Atlantic corals suggest that closed system aquaculture is a successful method of holding and propagating healthy corals for transplantation. Fate of transplanted corals tend to fare equally well among culture sites from which they originate, but some species (*e.g., Siderastrea radians, Stephanocoenia mechelinii*) fare better than others (*e.g.,* Faviid corals). In the course of this work, we have developed methods to characterize tissue architecture via histological methods, and the health of mucosal microbial communities. We also developed a health certification process acceptable for reintroduction purposes.

Our current research initiatives include testing culture methods for restoration of *Acropora cervicornis,* characterizing the variety of diseases encountered by coral aquarists nationwide, and assessing the effects of commonly used medications on coral health.

The January 2010 cold weather event has devastated extensive areas of reef habitat highlighting the need to pursue coral restoration efforts. As we look toward the future, we plan to include SECORE initiatives as a strategy to provide populations of seed corals for restoration, while making use of The University of Florida Tropical Aquaculture Laboratory's offshore lease site in the FKNMS for future research and restoration efforts.

Lessons on Creating a Joint Public Aquarium - University Partnership for Advancing Research, Husbandry, and Education

Michael Tlusty and Andrew Rhyne
New England Aquarium and Roger Williams University

Tuesday, June 8, PM Session

Collection and Tranport

Collection and Mock Transport of Atlantic Tunas

Forrest A. Young and C. Ben Daughtry
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Display of tuna and other pelagic species is widespread in Japan and other parts of tropical Asia. However few aquariums in the U.S. other than Monterey Bay Aq. display tuna and other pelagic species. The team collected a small number of blackfin, skipjack and bonito in an effort to look at several species and to demonstrate feasibility to provide these species to inland aquariums. Mock transport of blackfin tunas were also done with reasonable success.

Long-term Transportation, by Road and Air, of Chub Mackerel *(Scomber japonicus)* and Atlantic Bonito *(Sarda sarda)*

João Correia
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Flying Sharks

During the second semester of 2009 three trips were made from Olhão (Southern Portugal) to Stralsund (Northern Germany) carrying a total of 2.122 animals, which included multiple teleosts, elasmobranchs and invertebrates. This group included some scombrids, such as 1.869 Scomber japonicus and 9 Sarda sarda, which are notoriously difficult to transport. However, multiple adaptations to transport regimes adopted regularly have allowed the authors to successfully move these animals by road and air over a total of 24 hours. Such adaptations included maintaining oxygen saturation rates at approximately 200% and also the constant addition of AmQuel®, sodium bicarbonate and sodium carbonate.

Different formulations were used during the three trips, with the best results corresponding to 20 / 30 / 30 ppm of the three aforementioned chemicals, respectively. The authors suggest, however, that a modified formula of 20 / 40 / 40 ppm will allow for an even more stable pH throughout future trips.

Wednesday, June 9, AM Session I

Miscellaneous Topics

Sponsor Presentation – YSI

The Importance of Flow in Sea Dragon Development

Sandy Trautwein
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Long Beach Aquarium

The challenges associated with maintaining sea dragons are many, especially regarding newly acquisitioned juveniles. Proper development and success rate to adulthood can be greatly enhanced by establishing suitable flow during the developmental period. Appropriate flow assists in orienting juvenile sea dragons to a horizontal position thereby promoting feeding and growth rates. This reduces the occurrence of swim bladder issues and prevents scoliosis. The Aquarium of the Pacific's experience with newly acquisitioned sea dragons will be presented, including a review of the importance of flow to other syngnathid species.

Sound, Stress, and Seahorses

Paul Anderson, PhD
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The Florida Aquarium Center for Conservation

Loud noise in an aquarium generated by water pumps, chiller motors, airstones, *etc.* could represent a cacophonous acoustic environment for resident fishes. What effect does this have on fish health and behavior? I examined this question using the lined seahorse *(Hippocampus erectus)* as a model species. Public aquaria from throughout the United States were requested to record the acoustics of their resident seahorse tanks; these recordings were compared to ambient noise from sites in Tampa Bay where *H. erectus* were collected. Total Root Mean Squared (RMS) power of ambient noise varied widely but averaged 126.1 ± 0.8 (mean ± SE) deciBels with reference to one micropascal (dB re: 1 μPa) at the middle of the water column and 133.7 ± 1.1 dB at tank bottom, whereas ambient noise in the wild averaged 119.6 dB ± 3.5 dB. The auditory evoked potential (AEP) technique was employed to characterize the hearing sensitivity of *H. erectus.* This species' hearing sensitivity is characteristic of hearing generalist fishes, with a maximum spectrum-level sensitivity of 105.0 ± 1.5 dB at 200 Hz. Behavioral and physiological chronic stress responses of *H. erectus* to long-term noise exposure were also examined. Thirty-two seahorses were weighed, measured, and then housed individually in either loud (123.3 ± 1.0 dB at mid-level, 137.3 ± 0.7 dB at bottom) or quiet (110.6 ± 0.6 dB at mid-level, 119.8 ± 0.4 dB at bottom) tanks for one month. One-hour weekly behavioral observations were scored and tested. At the end of the trial, animals were euthanized, weighed and measured again, and blood was collected and processed for leukocyte differential. Animals housed in loud tanks declined more precipitously in weight change (-2.2 ± 0.3 vs. -1.4 ± 0.3 g) and change in Fulton body condition factor (-0.045 ± 0.009 vs. -0.002 ± 0.013). The heterophil:lymphocyte (H:L) ratio, an indicator of chronic stress response, was significantly higher for animals in loud tanks (0.88 ± 0.25 vs. 0.36 ± 0.7). Behaviorally, animals in loud tanks made more adjustments (69 ± 18 vs. 27 ± 7) on holdfasts in the first week, but habituated thereafter. By week 4, the pathological and concomitant distress behaviors of piping and clicking (respectively) developed among animals in loud tanks (piping: 106.9 ± 96.5 vs. 3.1 ± 1.1; clicking: 6.2 ± 3.2 vs. 1.1 ± 0.4). Together, behavioral and physiological results suggest a chronic stress response to long-term exposure to loud noise. Aquarists and aquaculturists are thus advised to consider the acoustic environments of their systems, and incorporate sensible soundproofing modifications in design.

Happy as a Clam: Artificial "Hinge" Replacement

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What do you do when you have a +35lb *Tridacna derasa* (Smooth Giant Clam) in an exhibit with a severely eroded outer ligament and dislocated hinge? Well, in most cases you would have a good argument to serve up a large plate of murugai sashimi for you and your fellow co-workers. We however, saw it as a great opportunity to experiment with several different artificial hinge designs and put a few of them to use.

Some information on "fixes" can be found online posted by hobbyists trying to repair smaller clam specimens, but information on repairing larger specimens is hard to come by. This presentation will go over the factors that were considered in the designs: impact of application of hinge to the clam, function once applied, overall aesthetics, and durability of the new hinge design. Details on the designs and procedures that were both successful and unsuccessful are provided, as well as modifications which were made nearly a year after the initial hinge repair was made.

Sponsor Presentation – New Era Food

The Shark Spine Study

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Sandtiger sharks *(Carcharias taurus)* have been plagued by the prevalence of spinal deformities among captive specimens. The Florida Aquarium Center for Conservation and partners launched the Shark Spine Study in 2008, requesting U.S. public aquaria to participate in a three-stage study occurring across the timeline of resident sharks: 1) a history and husbandry survey coupled with videography for ethological investigations, 2) hematology and radiography requested during health exams, and 3) a necropsy protocol upon expiration or euthanasia. Seventeen public aquaria submitted data and/or tissue samples from up to 67 specimens. Surveys reported 18 afflicted sharks (27%). Sharks caught off the Rhode Island coast and/or by pound net demonstrated a higher prevalence of deformity than sharks caught from other areas or with hook and line; these results merit further investigation into different collectors' capture techniques. Sharks usually presented with spinal deformity by a median of 4 years in captivity, compared to healthy sharks, which persisted for a median of 10 years. In captive environments, aquaria with smaller lengths (or diameters) had populations with higher disease prevalence. This is informative in light of swimming behavior; captive sharks (regardless of condition) spent a median of 95.5% of their time actively swimming and only 0.5% gliding, suggesting abnormal locomotion lacking parity between swimming and gliding that other species naturally demonstrate. Furthermore, sandtiger sharks with spinal deformity spent significantly less time gliding than healthy sharks. This is coupled with constant lateral stress on the vertebral column due to either clockwise or counter-clockwise swimming that accounted for a median of 99.7% of locomotion of sharks (regardless of condition), generally with a low occurrence of change in direction. Also, afflicted sharks carried more body mass per unit length.

Biomechanical analyses revealed that the flexural stiffness of intact vertebral columns and compressive stiffness, yield strength, yield strain, and ultimate strength of individual vertebrae from healthy animals were greater than those from deformed animals. However, the compressive stiffness and ultimate strength of vertebrae from healthy specimens were still lower than those of most species for which data is available, suggesting an inherent predisposition for spinal deformity in captive settings where natural swimming behavior is constrained.

Trials and Tribulations of Quarantining and Displaying Tiger Sharks, *Galeocerdo cuvier*, at Adventure Aquarium.

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Adventure Aquarium

In December of 2008 Adventure Aquarium acquired 2.2.0 *Galeocerdo cuvier* pups. The four pups were placed into a 40,000 gallon holding system for six to eight months. During this time biologists performed countless hours of observation and concentrated on manipulating their environment to prevent perimeter swimming, rostrum and caudal fin rubbing behaviors that have been commonly observed with this species in captive situations. There was also a strong focus on medical treatments, examinations, and several feeding/diet strategies were used to keep these sharks in good health. Morphometrics of the tiger sharks were monitored, adjustments were made to diet and as a result a fairly high growth rate was recorded. Three of the tiger sharks successfully survived quarantine and were each separately introduced to Adventure Aquarium's, 760,000 gallon Ocean Realm exhibit. While on exhibit similar manipulation of their environment and constant health monitoring continued. The experience of working with these sharks has been demanding and rewarding for the team at Adventure Aquarium.

Ultrasonography as a Tool in Managing Reproductive Cycles of *Dasyatis americana*

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The reproductive cycle of captive as well as wild Southern rays, *Dasyatis americana*, is not well documented. A variety of values for duration of gestation, age of sexual maturity and inter-pregnancy intervals are mentioned in the literature. Rays as well as other elasmobranchs are ectothermic and as such are greatly affected by the temperature of their exhibit or habitat as well as other environmental parameters such as salinity, photoperiod, diet, etc. These variables may account for different values reported from a variety of institutions and researchers.

Regular ultrasonography of female Southern rays can accurately define the reproductive cycles of exhibit animals. It is quick, easy to do, and non-invasive. Ultrasonography can be coupled with plasma chemistry testing of various hormones to further define the animal's cycle. *D. americana* is viviparous and carries 3-6 embryos in a uterus lined with villi referred to as trophonemata. The embryos live off of their yolk sacs in the early stages of the pregnancy but ingest an organically rich histotroph secreted by the villi during the remainder of the pregnancy. Ripley's Aquarium, Myrtle Beach did a monthly reproductive census of its Southern rays for over a year. Using the ultrasound, a staging protocol was developed that allowed the staff to keep track of each individual's reproductive cycle. It provided information that helped define the cycles of this species in captivity. Captive rays have one to three pregnancies in a 12 month period. Because the results of this protocol have proven useful from a practical as well as academic point of view, the program has been expanded to include our collections of cownosed rays and spotted eagle rays.

Wednesday, June 9, PM Session I
Cephalopods

Sponsor Presentation – CalAquaria

Displaying and Breeding Dwarf Cuttles

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As opposed to the larger species of cuttle regularly kept in public aquaria, *Sepia bandensis* is a small Indo-Pacific species that can be kept in reasonable size aquaria while displaying all the behaviors that make their larger cousins such crowd pleasers. At the Steinhart Aquarium we have raised these animals from eggs, documented their mating and egg laying (on display), and are preparing to display our second generation in the near future. This presentation will cover the care and breeding of this overlooked, fascinating, easy-to-house cuttle.

Nautilus Husbandry in the 21st Century

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The goal of this study was to look at current husbandry methods of a sensitive species as *Nautilus* is. There are still many questions unanswered when It comes to nautilus husbandry. Beginning from the basics may be the best opportunity in improving husbandry and developing a captive breeding program.

Data from several institutions regarding their husbandry operations on nautilus has been analyzed and compared to other institutions. It appeared that several factors were similar between institutions but there were also several parameters that were inconsistent at different places. Temperature ranges appeared to be similar throughout most of the aquariums though many of the institutions' target temperature were different. All of the aquariums fed their nautilus shrimp as part of their diet. Some of these institutions only fed shrimp to their nautilus while others fed a different variety of food. The most interesting data may be the amount of food fed to a single nautilus and the stocking densities of nautilus. There does not appear to be any consistency of feedings between aquariums. Stocking densities appear to be based upon water quality limitations rather than behavioral or growth impacts.

Apparent Mimicry Behavior Displayed by the Pharaoh's Cuttlefish, *Sepia pharaonis*

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Cephalopods are well known to use color and shape changes to attract prey or mates, and deter predators or competition. Many organisms, including cephalopods, use mimicry to achieve the same goals. Only a few cephalopods have been known to use their color and shape changing ability to mimic another, if not multiple other, organisms. Observations of the Pharaoh's Cuttlefish (*Sepia pharaonis*) at the Oklahoma Aquarium suggest that it may be a candidate for this small list of mimicking cephalopods. Three juvenile *S. pharaonis* appeared to mimic hermit crabs during periods of foraging and stalking prey. They resembled the physical characteristics of a hermit crab: the body shape, color, and body movement. As this behavior has not been reported in other specimens, it is clear that no solid conclusions can be made about the species' ability to mimic. However, the observed behavior from these few cuttlefish combined with their intelligence and unparalleled ability to change shape and color requires further investigation.

***Euprymna scolopes* Husbandry at the University of Wisconsin**

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The McFall-Ngai and Ruby labs have been studying the symbiotic relationship of the Hawaiian bobtail squid (*Euprymna scolopes*) and the bacterium *Vibrio fischeri* for more than 20 years. The labs had previously been located in California and Hawaii, before relocating to Wisconsin in 2004. The current husbandry and care of *Euprymna scolopes* is discussed in this presentation, noting limitations of a Midwestern land-locked location.

Adult *Euprymna scolopes* are collected 2-4 times yearly from Hawaii. We have had great success in breeding and hatching eggs. Thousands of hatchlings are produced from each adult collection, and are used for study by the graduate students and post-docs in the lab. Longevity and fecundity data from 2008 to present will be provided.

Wednesday, June 9, PM Session II
Exhibits and Construction

Sponsor Presentation – Living Color

Species Lists, Stocking Plans, Setbacks and Successes: Developing the Steinhart Aquarium's Philippine Coral Reef

Bart Shepard
Steinhart Aquarium – California Academy of Sciences

If You Build It, They Will Come

Kirk Embree
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Central Campus Aquarium Science, Des Moines Public Schools

Corn won't be the only thing grown in Iowa after the grand opening of the newly renovated and expanded Aquarium Science/Marine Biology program opens at Central Campus in Des Moines, Iowa next Fall. The high school programs provide college credit for both Aquarium Science and Marine Biology. The current program offers students PADI dive certification, an education in the diversity of organisms that live in the ocean, training in the husbandry techniques required to keep these aquatic animals alive in captivity, and the opportunity to participate in a two and a half week long ecology field study in Florida. The Aquarium Science program will provide specific training geared toward a career as a public aquarist or in the ornamental marine aquaculture field in our newly constructed 9,500 sq. ft. / 13,000 gallon marine lab and aquaculture facility. The labs renovation was conceptually designed after a public aquarium in which presentation and education is key on the Marine Biology half and conservation is emphasized on the aquaculture side. A strong emphasis will be placed on the aquaculture of small ornamental marine fishes, live coral propagation on our coral farm, and of course Moon Jellyfish production. The presentation will include a visual tour of our new educational facility and a peek into what the oceans look like in Iowa.

Vancouver Aquarium's Canadian Arctic – A Chilling Experience

Dennis A. Thoney, Ph.D. and Danny I. Kent
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Vancouver Aquarium

The Vancouver Aquarium completed renovation of its 20 year old Arctic gallery in November 2009. Not only was the original beluga exhibit gallery well worn, messaging was dated. The gallery also lacked any aquaria displaying Arctic fishes and invertebrates. The recent interest in Canadian's Arctic and problems associated with global warming prompted the $1.3 million renovation which includes five aquaria and extensive audiovisual components. Logistics associated with the collection of Arctic fishes were complex. Two collecting trips, one using traps and angling through the ice in spring and one SCUBA diving in late summer, provided sufficient animals for the exhibits. Various octocorals, anemones, mollusks, crustateans, pycnogonids, basket stars, asteroids, and fishes (Arctic cod, zoarcids, and cottids) were collected. Animals were placed in plastic bags with cold water and oxygen and packed in insulated containers with snow to maintain temperature on the long transport of up to 100 hours. Condensation was a major problem in the holding room at VA where tanks were kept below 3^{o} C. Even with insulated tanks, air conditioning was necessary to reduce humidity. Four of the exhibit tanks that also were maintained below 3^{o} C were constructed with two inch thick acrylic windows to prevent condensation. All pipes, sand filters, sumps, and foam fractionators had to be insulated. A large fan was needed to reduce condensation behind the exhibits. The sixth tank, a six foot cylinder exhibiting Arctic char, is maintained from 6-12^{o} C, allowing only one inch thick acrylic to be used in construction of the tank. Char eggs were obtained from a hatchery in the Yukon Territory, raised at the aquarium, and placed on display in the cylindrical tank. The animal exhibits and most of the graphics are located along the back wall to maintain a large open gallery space for night events. Electronic multi-touch table interactives located in the open area of the gallery can be rolled out when required. Although the cost and manpower required to obtain the Arctic animals was significant, their addition to the beluga whale gallery was worth the effort.

Ocean Adventure; Conservation in Action

Bianca Espinos (Intro by Greg Whittaker)
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Ocean Adventure was developed as a low impact marine park in a protected rainforest and marine reserve in Subic Bay, Philippines. Originally designed as a small scale open water marine mammal and aquarium facility, the scope has expanded greatly since its opening in September, 2001, and is now recognized as a premier destination for the greater Manila area. With an inherent stewardship in its mission and a cutting edge animal care system, the facility serves as a collaborative partner with the Philippine Department of Natural Resources. This close relationship has allowed Ocean Adventure to achieve a unique standing as a for-profit entity with direct links to government conservation initiatives. The physical location creates a platform for both immersive ecotourism and conservation research.

Ocean Adventure serves as the marine mammal stranding center for the northern Philippines as well as the regional sea turtle stranding, rehabilitation and nest protection resource. The waterside operations team actively patrols and protects the southern half of outer Subic Bay. The aquarium and dive staffs monitor water quality and reef diversity as a long term environmental protection study. The recently approved master plan adds a terrestrial component to more thoroughly interpret the undisturbed rainforest watershed surrounding Illanin Bay. The current beach resort and conference facility will be augmented by terrestrial based lodging to accommodate the increased demand for ecological focused workshops.

The fundamental commitment to natural immersion, environmental stewardship, low impact development and community building has allowed Ocean Adventure to truly walk the conservation and education walk while maintaining a financially sound development track.

Thursday, June 10, AM Session I

Miscellaneous Topics

Sponsor Presentation - ISIS

Exhibiting Non-Releasable Green Sea Turtles *(Chelonia mydas)* with Posterior Float

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In 2002, an adult female Green Sea Turtle (Chelonia mydas) became the first sea turtle exhibited for the Shark Reef Tank (900,000 gallons) at Omaha's Henry Doorly Zoo. Upon arrival and placement in a quarantine tank the turtle exhibited a posterior float. A CT scan, performed at a local hospital, revealed excessive amounts of gas in the intestines. Trauma to the turtle's carapace, prior to stranding, may have damaged intestinal nerves leading to the excess build up of gas and the subsequent floating syndrome. Medical management has, so far, proven unsuccessful. However, the addition of a weight pouch to the posterior carapace has provided the turtle neutral buoyancy, greatly increasing the ability of the animal to demonstrate natural behaviors in the exhibit tank.

A New Era in Aquarium Husbandry – ZIMS

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ZIMS (Zoological Information Management System) is a new program created by ISIS (International Species Information System) that will replace the outdated ARKS (Animal Record Keeping System) program and will include for the first time complete Aquarium functionality. ZIMS is an international web based program that will help standardize the global Aquarium community and will ultimately create industry "best practices". Specific Aquarium benefits include, but are not limited to, working with and creating databases for individuals, groups and colonies which can then be merged or split without losing valuable information and history. Tank and life support system history can be tracked as well as also being merged and split. Water quality data can be logged in a table format specific to daily operations as well as tagged to animals and tanks with notifications to selected personnel. Collecting trip data can be logged and tagged to individual animals or groups/colonies. Daily tank log reporting including feeding, measurement, tasks performed and observations. Includes the ability to generate an instant census and permit reporting in specific formats. Also provides an infinitely building database of information that can be queried in an unlimited number of ways and data can be graphed for historical trends. It is also planned that ZIMS will be used by the research community as well as private and government sectors for such things as tracking and preventing zoonotic diseases for example. ZIMS has been built by our worldwide Aquarium and Zoo community for our worldwide Aquarium and Zoo community.

New Approaches to an Open System Reef Tank

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Birch Aquarium at Scripps

During August/September 2008 the Birch Aq took down its 14 year old 1200 gallon live coral exhibit. A number of changes were made to the exhibit tanks and its life support system in order to provide a better home for a completely new reef display, which opened at the end of September 2008. A Fijian themed tank, depicting an upper reef slope was created.

The goal for the exhibit was to create an environment where mass spawning events of Acroporids might take place and that the gametes from those spawns could be utilized for fertilization and propagation. To this end, a number of measures were taken to enhance water quality and maintain more control over water temperature, given that this tank runs open system.

This presentation offs a view of our new "in house" approach to maintaining a reef exhibit, which runs open system. While the new set-up takes advantage of the positive aspects (dilution of nutrients, consistent salinity, consistent major, minor and trace elements), of our incoming seawater, it also attempts to eliminate the negative aspects (detritus, plankton, dissolved nutrients, changing temperatures).

A New Aquarium for a New Age of Sustainability

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Steinhart Aquarium, California Academy of Sciences

Thursday, June 10, AM Session II
Culturing

Sponsor Presentation – Piscine Energetics

Captive Reproduction of the Boarfish (*Capros aper*)

Jay Hemdal and Todd Gardner,
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Toledo Zoo and Atlantis Marine World

The boarfish, *Capros aper* is found at depths of 40 to 700 meters in the Eastern Atlantic and Western Mediterranean. This species is not frequently exhibited in public aquariums, but they are hardy, colorful and fairly peaceful. A group of seven fish were acquired from the Musée Océanographique in Monaco in 2002. Courtship was noticed in 2007 and viable eggs were removed from the exhibit by net in 2008 and 2009. Approximately 45 collections of eggs were made during those two years. Of the 37 groups of viable eggs incubated at the Toledo Zoo, survival of the resulting larva ranged from one to 26 days, with none reaching the post-flexion stage. Longevity increased when *Tisbe* copepod nauplii were introduced as a food item to augment the “s” strain *Brachionus* rotifers that were used at first. Six groups of eggs were shipped to Atlantis Marine World. They were able to raise one larva using cultured *Acartia hudsonica* copepod nauplii as part of the diet. This fish is now a sub-adult, and is being housed at the Toledo Zoo.

Jelly Culture: Transitioning from Sub-Adult to Adult Medusa in *Chrysaora* Species

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The display of jellies requires the culture of the life cycle from polyp, to strobilation of ephyra, to grow out of ephyra to adult medusa. For species of Chrysaora and other medusavores, this entails the propagation of moon jellies as well to feed to the growing Crysaora. During the run of “Jellies, Phantoms of the Deep” at the Aquarium of the Pacific in Long Beach I successfully supplemented the use of moon jelly mesanglea with diced and whole tubifex worms to successfully transition sub-adult East Coast Nettles *Chrysaora quinquecirrha* and Purple Stripe Jellies *Chrysaora colorata* to adult medusa.

During the grow-out of the ephyra, in addition to diced messanglea, I would dice tubifex worms (Tubifex tubifex) into pepper-sized bits. I would transfer the ephyra from the grow-out container (an 8” diameter x 3” tall peitry dish) into a regular sized pietry dish into which I would add the diced messanglea and tubifex worms. The ephyra would stay in this pietry dish for approximately 20 minutes during the cleaning of the grow-out container, then be added back to the cleaned grow-out container. Whereas bits of mesanglea were difficult to see when adhered to
the ephyra, the bits of tubifex worms could be clearly seen.

When the ephyra were approximately .5 to 1cm in diameter they would begin to develop one or two tentacles. I refer to ephyra at this stage as sub-adults. At this point a whole tubifex worm would be placed in the peitry dish with the ephyra. When the worm comes in contact with a tentacle it becomes entwined and its thrashing pulls the sub-adult to it. At this point the sub-adult medusa are transferred to a mini-pseuto kreisel for grow out. As the sub-adults matured into young medusa, the worms would be transferred to the oral arms. At this stage a second offering of worms would be fed in the afternoon. As the young adults continue to grow, more worms are offered during feeding, paying close attention to not over-load the jelly with more food than it can comfortably swim with.

The ease of acquiring tubifex worms reduces the reliance on moon jelly mesanglea in the grow-out of east coast nettles and purple striped jellies. I believe this technique can be transferred to other species of Chrysaora with similar success.

The Versatility of the Spot Prawn, *Pandalus platyceros*

Jennifer O'Quin
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Aquarium of the Pacific

The spot prawn, *Pandalus platyceros*, is the largest species of shrimp found along the US West Coast and is a commonly displayed aquarium animal. Mating in this species occurs only once or twice in an adult's lifetime. In the spring of 2009, The Aquarium of the Pacific had its first successful rearing attempt of spot prawns using a single gravid female. With this hatch, we were able to boost our lagging inventory with almost 450 prawns. By the time the juveniles were four months old, they were put on display in a small 22 gallon focus exhibit and by seven months, they had grown large enough for our 1,000 gallon Sandy Bottom exhibit. Once the juveniles were nine months old, we transformed our North Pacific touch lab into a shrimp touch tank, which has become a huge hit with guests.

This year, I expanded the rearing system to hold 5 gravid females off exhibit. The eggs from each female were in various stages of development, which allowed us to be creative and exhibit the larvae in a pseudokreisel for public display, replacing one of our jelly exhibits. Since the larvae settle out of the water column within a month of hatching, we were able to continuously rotate them out as needed and restock with newly hatched larvae. Surplus spot prawn larvae were used as a supplemental prey item for our weedy and leafy sea dragon collection. All in all, prawns are very versatile animals. In this presentation, I will go into detail about our rearing setup, culture techniques, and larval growth and development of this species.

Breeding and Raising *Chrysaora fuscescens*: A Look at How Everyone's Doing It

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Tennessee Aquarium

The potential size and attractive coloration of *Chrysaora fuscescens* medusa, the west coast sea nettle, has made this species a very popular and desirable exhibit animal. Although many aquariums display this species, most find culturing and growing these medusas difficult and unreliable. In a survey of public aquariums taken in early 2010, institutions keeping *C. fuscescens* were asked a variety of questions pertaining to the general husbandry, captive propagation, health, water quality, and housing of this species of jellyfish. This collected information has been organized and will be presented in an attempt to better the husbandry techniques and captive propagation of this species.

Friday, June 11
Coral Symposium

Here is the Deal with Coral Reproduction, What We Think We Know: A 101 Review
Bob Snowden

Methods for Calcium and Alkalinity Maintenance
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One of the most critical components of maintaining calcareous organisms in closed systems, be they corals, clams or algae, is the ability to provide adequate levels of the building blocks necessary for the growth of their calcareous skeletons. This presentation will focus on various methods for sustaining desirable levels of calcium, alkalinity, pH and magnesium. Techniques such as water changes, calcium reactors, calcium hydroxide solutions, two-part solutions and manual additions will be discussed including their pros and cons.

Coral Parasites and Their Destruction
Rob Brynda
Landry's Downtown Aquarium, Denver

Water Flow for Stony Coral Systems
Richard Ross
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Steinhart Aquarium, in the California Academy of Sciences

Flow is critically important for the health and growth of corals, but how much flow is enough flow? This presentation will discuss some of the reasons why corals need flow, and look at both simple and complex strategies for creating appropriate flow in captive coral systems.

***Acropora* sp. Growth under Plasma Lighting**
Matt Wandell
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California Academy of Sciences

The standard for providing sufficient lighting for reef building coral growth in large displays has been metal halide lighting. Plasma arc lighting offers many potential benefits compared to metal halide lighting but its long term suitability for growing corals has not been demonstrated. We grew fragments of an *Acropora* sp. coral under metal halide and plasma arc fixtures to compare growth rates.

Panel Discussion

__Afternoon__: Wet Lab at zoo, including build it yourself projects and propagation workshops

Saturday, June 12
SECORE Workshop

- Practical part 1: collect with the group larvae from aquarium colonies.
- Lecture session 1: basics on coral reproduction biology and breeding techniques.
- Practical part 2: i.e. study collected larvae (microscope), study settled polyps and juveniles at different ages.
- Practical introduction to different collection techniques and/or husbandry techniques for raising juveniles.
- Lecture session 2: SECORE initiatives and coral conservation: SECORE field workshops, Curacao program.
- Parting Words.

POSTER ABSTRACTS

Raising *Limulus polyphemus* in a Closed System

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At the Fort Worth Zoo, horseshoe crabs Limulus polyphemus is a permanent part of our collection plan. In the past, there has been some difficulty finding specimens for our exhibit. Because of this, raising these animals has become an interest to us in order to not rely only on a wild caught source.

There is not much information available on breeding let alone raising L. polyphemus in captivity. It has been our observations over the past year that these animals can be raised in captivity to a large enough size to be exhibited in smaller touch tank setups. These animals require only a few hours per week given the proper setup. They are extremely tolerant of a wide range of water quality parameters and handling which is a advantage over other species of aquatic invertebrates.