DRUM *and* CROAKER

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DRUM AND CROAKER 35 YEARS AGO

Richard M. Segedi

(Brief excerpts from D. & C. Volume 15 (74) Number 1, edited by John G. Shedd Aquarium)

Shifting Dolphins - *Herman Buttron, Senior Lead Keeper, Seven Seas Panorama, Brookfield Zoo*

A positive control system can be a movable barrier arranged so its operation gives the dolphin no alternative but to swim into the desired area.

Generally, even trained jumpers will not leap over things they have not been conditioned for. Even so, it has happened and any design for a controlling mechanism must be planned to eliminate that possibility. The above water part of the barrier must be imposing enough to discourage thoughts of jumping it.

Thematic Displays: Aquarium - *U. E. Friese, Curator of Aquarium, Tonga Zoo*

There is virtually no limit to the range of biological topics that can be demonstrated or commented upon in relation to any exhibit . . . However, a properly planned aquarium might well begin by providing exhibits that illuminate the implications of pollution and destruction of the environment, the structure of animal communities, animal societies, aggression, and the ways in which species are adapted to their environments, and cope - or fail to cope - with natural or man-made changes in their habitats.

Reproduction in the Giant Octopus of the North Pacific - *Susan Gabe, Vancouver Public Aquarium*

As is usual among brooding octopuses, the female took exceptional care of her eggs, continuously agitating them with the tips of her arms. . . .

After hatching the young were removed and placed in tanks ranging from 10 to 30 gallons. . . .

A variety of foods was offered the young octopuses. These included egg yolk, ground shrimp and mussel, live gammarids, live brine shrimp (both young and adult stages) and fry of the Red Irish Lord sculpin *Hemilepidotus hemilepidotus*. Of these only the fry and the adult brine shrimp were accepted and these only when offered in sufficient quantities. Brine shrimp - the food more often taken - were added to the tank in densities of approximately 100 per litre. If supplied in small quantities, neither the fry nor the brine shrimp were eaten.

Demonstrations of Ecological Concepts by the Alewife in Lake Michigan - *Beverly Serrell, Shedd Aquarium*

Prior to 1949 there are no records of [alewife] occurrence in Lake Michigan. The alewife entered Lake Michigan and became established by 1954 after migrating through Lakes Huron and Erie, the Welland Canal, and Lake Ontario (Miller, 1957). How it came to be in Lake Ontario in the first place is a matter of speculation. Most likely it arrived on its own through the St. Lawrence River or the Erie Canal (Miller, 1957). But it may have been introduced inadvertently along with shad, *Alosa sapidissima* (Wilson), or it may have remained in Lake Ontario after the last glacial epoch.

Note From National Aquarium:

A slide program of the nesting of the Loggerhead Sea Turtle is available, complete with script, through the Education and Information Department; National Aquarium; Bureau of Sport Fisheries and Wildlife; Washington, D. C. 20240

NOTES ON CAPTIVE PROPAGATION AND REARING OF ZEBRA SHARKS, *STEGOSTOMA FASCIATUM,* AT JOHN G. SHEDD AQUARIUM

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Breeding/Copulation

In 2003, Shedd Aquarium acquired two adult zebra sharks that were collected off the northeast coast of Australia. The male came to our facility in January with the female joining him later that year in August. Upon arrival the female weighed 35.2 kg and had a total length of 197 cm. The male weighed 31.7 kg had a total length of 196 cm and a clasper length of 16.5 cm.

Shortly after arrival our pair began exhibiting pre-copulatory behavior that primarily included the male grasping onto the caudal fin of the female while swimming. After taking hold of her fin, the female turned upside-down in the water column, gradually sinking to the floor of the exhibit. With both animals now on the bottom, the male would either hold on to her caudal fin or grasp her pectoral fin. This behavior occurred frequently throughout the year, continuing for several hours at a time occasionally concluding with copulation. When copulation was observed, the female was usually receptive and once she reached the sandy floor of the exhibit, would lie motionless allowing the male to position himself for intromission. During times when the female was less receptive he would position the female against the artificial coral habitat, restricting her ability to move away from him.

Egg-laying

On April 1, 2004, egg production was first observed. From 2004 until August 2008, our reproductive female laid a total of 313 eggs resulting in 78 births. Up to seven eggs have been laid at a time although four to five is more typical. Eggs are laid in six to eight day intervals continuously for a period of four to five months. Our reproductive female is housed in either our exhibit (30 m length x 10 m width x 5.5 m depth) or medical pool (9 m diameter x 1.2 m depth) at different times throughout the year. In the medical pool, a pile of cinder blocks has been added to provide a substrate for depositing her eggs. On exhibit, she routinely lays her eggs within a small selected area of artificial corals.

Several days before egg-laying occurs, attachment tendrils can be observed at the opening of her vent. Because egg-laying typically takes place during evening and early morning hours, video surveillance provided us an opportunity to observe her behavior. Our female would swim in tight circles around the rockwork, cinderblocks or artificial corals she was attempting to lay her eggs on while rubbing her vent on the structure and oscillating her body back and forth. As she began to expel the eggs, the tendrils would attach to the structure pulling subsequent eggs from her oviduct. Similar egg laying behavior was described by Kunze and Simmons (2004). Within thirty to sixty minutes egg-laying was completed. The length of time would depend on the number of eggs being laid.

Egg Handling and Incubation

Eggs are collected shortly after being deposited and are brought to the surface by divers using a large plastic container sealed with a lid. The eggs are then transferred to floating baskets located off exhibit within the main shark water system, which allows husbandry staff better access. Efforts are made to keep the eggs underwater during the transfer however if they are exposed to air, the egg is submersed with the blunt end of

the egg pointing upward. Gentle pressure is applied to the egg to expel any air that may have become trapped inside. Attachment tendrils are removed from the eggs to prevent entanglement of the hatching neonates. Tendrils can be removed by gently peeling them away from the egg. A large gauge needle is inserted through the tapered end of the egg to create a small hole. A loop of monofilament would be strung though for attachment of dated label. The eggs are then placed into floating baskets near the filtration skimmers to help maintain adequate circulation.

Approximately 30 days after eggs are deposited, they are ultrasounded to determine fertility. Direct imaging of active embryos confirms viability, but young embryos (less that 30 days old) can sometime be difficult to image. A well defined, uniform, oval, dependent yolk is used to gauge potential viability when an embryo cannot be visualized. Rotten or infertile eggs will not contain a discrete yolk (Poll, pers. comm.). Confirmed fertile eggs are moved to a hatching basket or to one of the 870 liter cylindrical enclosures plumbed onto the shark system. An airstone is kept in the enclosure to help provide adequate circulation. Eggs are suspended from a PVC pipe placed across the top of the enclosure by the monofilament previously inserted through the egg. If fertility is questionable, the eggs remain in the floating baskets for an additional month and are ultrasounded again. Embryo development is monitored on a four to six week basis through the use of ultrasound. Candling these eggs is more challenging than with smaller species of elasmobranchs because of the thickness of the egg wall. A bright underwater flashlight is recommended to get maximum results, however, smaller embryos that can be visualized with ultrasound may be difficult to see when candling. One method for candling is described as holding the egg as level as possible, with the light placed directly beneath the egg shining straight up to avoid shadows cast by the yolk (Kunze and Simmons, 2004).

At Shedd Aquarium, the incubation period for the eggs has consistently been 158–161 days (n=78) at 25–26 C. Water temperatures remain constant within this range throughout the incubation period. There appears to be a relationship between temperature and incubation period with an increase in temperature resulting in a decrease in the length of incubation (Kunze and Simmons, 2004; 1999. Henry Doorly Zoo).

Hatching

Upon hatching, neonates are photographed for identification purposes. Body weight, total length measurements and gender determination is also recorded. The pups are moved to 125 cm diameter circular tubs that recirculate on the main shark water system, where they are housed for approximately four months before being dispositioned to other institutions. No more than two pups are held in each enclosure.

Rearing

Once the neonates have hatched they typically find their way to the bottom of the habitat and lay down. Frequently, neonates will swim in tight loops for the first days after hatching, but quickly learn to navigate normally. Because they spend so much time on the bottom resting, we always provide a layer of sand or aragonite substrate for them to lie on. Animals may develop ventral dermatitis or pressure sores when substrate is not present or is in insufficient quantities. Respiration rates appear to be rapid in comparison to adults, about 60 respirations per minute in resting neonates. Respirations can reach approximately 80 respirations per minute when an animal is active or stressed.

After hatching, it is common for a yolk sack to be present on the undersides of some individuals. Typically neonates will begin to feed one to two days after they hatch but are presented with food from a feed stick starting on the first day. The food is placed directly in front of their mouths to encourage them to eat. Records of food item preferences and intake are recorded. Neonates are fed twice a day from a feed stick for

the first four to six months. Food is always presented on a feed stick since food left on the bottom of the enclosure is not readily accepted. This technique also enables better control over food intake. Once a pup's weight exceeds 1 kg, feeds are gradually reduced to once a day.

Juveniles continue to be fed on a daily basis until their daily food intake reaches 250 grams per feed. At that point the juveniles are shifted to a five time per week schedule.

Initially, the pups are offered bite-size pieces of food weighing 1-2 grams each, but as they progressively get larger, so do the food items. A variety of food items are offered at each feeding such as bonita (*Euthynnuus alleteratus*), clam (*Spisula solissima*), squid (*Loligo opalescens*), and shrimp (*Rivulogammarus pulex*). Other items are also offered, but not accepted as readily by juveniles. These include herring (*Clupea harengus*), capelin (*Mallotus villosus*) and Spanish mackerel (*Scomber japonicus*). Food items are prepared with skin and bones removed then soaked for fifteen minutes in a liquid vitamin supplement (Vita Fish™ Marine Enterprises International, USA) prior to each feeding. Any uneaten food soaked in vitamin supplement is discarded after the feeding.

Juveniles at Shedd are usually fed to satiation at each feed, however one individual developed gastrointestinal problems that were alleviated by restricting his diet. Ultrasonographic examination revealed a full stomach with apparently slow gastrointestinal transit. It appeared that once the animal's stomach became distended it would swim in spirals, perhaps from discomfort, but once he was fasted for a day and started on the restricted diet, the issue seemed to resolve (Poll, pers. comm.). Caution must be used when restricting the diet; due to their rapid growth rate their intake must be sufficient to meet their metabolic needs. Growth is monitored through monthly weight assessments for the first four to six months. More frequent monitoring is necessary when health issues are suspected or being addressed.

Progressively larger enclosure space should be readily available for neonates, as their growth rates are incredibly fast. Juveniles averaging 105 gms and 31 cm at birth have grown to nearly 1 kg and 70 cm within 120 days. Animals that do not have adequate space can abrade their rostrum from rubbing against the walls. We have observed animals moved from a smaller habitat into a larger one will frequently keep the swim pattern they had in the old habitat. This may appear that they are spiraling and having neurological issues, but after a few days they usually adjust and start to swim along the perimeter of their new enclosure.

A number of challenges rearing zebra sharks have occurred including bacterial infections, erratic swimming behavior, gastrointestinal motility problems and inanition.

The number of pups in our initial group was quite large and hatched within a short period of time, quickly exceeding our ability to house them properly. Suddenly overcrowding became an issue and systemic bacterial infections set in shortly thereafter. The group was treated with antibiotics chosen by blood culture and sensitivity. After some initial mortality, individuals began to improve with this therapy. Bacterial infections occur from a number of underlying causes including overcrowding and trauma from being housed in inadequate enclosures or water quality.

Erratic swimming behavior has been noted from a number of institutions that have reared zebra sharks however the underlying causes may be varied (Irvin, Drinnen, Celt, pers. com.). As previously discussed, in one case, excessive food intake apparently caused discomfort that presented as erratic swimming behavior. In other cases, neurological problems are presumed to be present but are difficult to confirm with medical

diagnostics. One postmortem examination revealed the evidence of possible developmental issues with the cerebellum of an individual (Poll, pers. comm.) Although the cause is unknown, viral exposure or possible nutritional deficiency has been considered. After receiving this report we began soaking all the foods offered to our neonates in vitamins in an attempt to prevent future problems.

Sudden onset of inanition often occurs in the days just prior to death despite animals having an established history of feeding well and otherwise appearing normal. Cause of death is generally determined to be hepatic atrophy, lipid depletion and emaciation but the underlying reason for the inanition still remains undetermined. Some instances may be related to gastrointestinal motility problems. Although we have not determined a definitive cause, we have had success with resolving some cases by gastric lavage using warmed Pedialyte™ (Abbott Nutrition, Columbus, Ohio, USA). While visualizing the stomach with ultrasound, an 8 or 10Fr red rubber feeding tube (Kendall Sovereign™, Tyco Healthcare Group LP, Mansfield, MA, USA) is passed into the stomach, ingesta is removed by aspiration and electrolyte solution is flushed into the stomach (Poll, pers. comm.). The procedure was repeated until the stomach was empty. Several gastrointestinal protectants and motility agents have been tried, but their efficacy is uncertain. The animal was supported through periodic assist feeds with baby shark/stingray gruel (Table 1) until voluntary feeding resumed sixteen days after onset of anorexia. Although this individual recovered, he never ate as much as the rest of the group he was housed with and was significantly smaller than other neonates his age. Henry Doorly Zoo (Omaha, Nebraska. USA) also reported a similar issue that resolved with this therapy (Cook, pers.com.).

"Anemia" has also been noted in several postmortem reports. However, no normal blood values have been established for this species and recent in-house studies suggest extremely low hematocrit levels in clinically normal juvenile pups (Poll, pers.comm.). With the last group of pups reared at our aquarium (n=8), we began to perform monthly physical assessments that included collecting total length, girth measurements, body weight and blood for analysis. We are attempting to develop a morphometric and blood value database for juveniles to determine normal values. Our preliminary results show low hematocrit levels in juveniles that gradually increase with each successive evaluation. Blood draws are initiated approximately 50 days after birth and repeated monthly for three successive months before the animals are dispositioned to other institutions.The initial hematocrit levels ranged from 9-13% that gradually increased to 15–17% by four months of age. We continue to work with the institutions that have our offspring to collect hematocrit and growth data in six month intervals. This study will help improve our clinical assessments of both healthy and ill animals and highlights the importance of objective data collection and the establishment both a normal growth curve and hematology reference ranges.

We raise the pups at our institution for a period of four to six months before dispositioning them to other institutions. Although they are a sedentary species shipping them has presented a number of challenges as well. Because they quickly outgrow standard shipping boxes we acquired a system of inflatable shipping liners (Coldpack system, San diego, California, USA) and cardboard boxes (69cm x 37 cm x 28.5cm) that will allow us to hold the animals for a longer period than had previously been possible. Our experience has been that they do best with shipping periods totaling twelve hours or less.

Population Management

Initially our adult male and female were housed together on exhibit for the first eleven months since their arrival. Concerns arose regarding the frequent caudal and pectoral fin wounds on our female, caused by repeated trauma from mating attempts. In July 2004, our female was moved to the medical pool located adjacent to the exhibit pool to enable us to provide treatment and prevent further injury. Several institutions

have reported septicemia and subsequent mortalities arising from this type of wound therefore we consider this to be a serious management issue. These wounds required the application of topical treatments as well as systemic antibiotics based on findings of skin scrape, culture, biopsy, or blood culture, although mild wounds may receive only observational monitoring. This also warranted the separation of our male and female populations between our exhibit and medical pools. We move our adult male in with the females once a year in order to have better control over their reproductive output and to prevent repeated trauma. Whenever our adult male has access to our adult female, precopulatory behavior begins within minutes of their introduction.

Since we began managing our adults this way we've experienced a decrease in the number of fertile eggs laid but an increase in the birth weight of our pups. We are unsure if the observation is simply coincidental or if there is a correlation but our initial birth weights averaged 87 gm prior to controlling copulation with subsequent weights averaging 102 -105 gms. The long-term viability of the pups also improved although a number of management practices have also changed with each successive group including improved housing and feeding practices. We believe a combination of factors has resulted in this overall improvement.

We continue to work on refining our captive breeding program and are in the process of beginning to study the genetics of our population to learn more about our collection. One objective of the project is to determine paternity of our offspring. Although we have one definitive mother, there are two potential sires. Parthenogenesis has been documented in other species of elasmobranches, so this is a possibility as well. The other objective is to learn if any of our animals are related since five of our six animals were collected from the same location off of the Northeast coast of Australia. Since some of the animals arrived to Shedd at the same time and at very similar sizes we believe it is likely that some may be related to one another. In order to guarantee as much genetic diversity as possible, and to responsibly manage breeding, animal care staff would like to know that these animals are not related.

Table 1. Baby shark/stingray gruel. Recipe developed by Shedd Aquarium Animal Health Department. You may need to add small amount of balanced electrolyte solution to smooth out the ingredients. This will make processing much easier. Please process until you can pass the mixture through a large metal feeding tube. Discard any large strands of fibers.

Quantity	Ingredient
75-80% by weight	Spanish mackerel filet (no skin, fibrous tissues, or intestine; these organs are difficult to blend and will clog up the feeding tube)
20-25%	Other fish and shrimp (no squid for the same reason as above)
100 cc	PRN Pharmacal "STAT"
100 cc	Cod Liver Oil (CLO)
12" (~20 g)	EVSCO "Nutri-Cal"
2-3 sheets	moistened seaweed (nori)
1 tablet	Mazuri vitazu shark vitamin/1,000 cc food

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FEEDING OCTOPUSES LIVE CRABS IS GOOD ENRICHMENT

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In the past we have advocated the use of live marine prey as food for enrichment for captive octopuses (Anderson & Wood, 2001). This includes prey items an octopus might encounter in the wild. Such food items are tried and true and efficacious of good octopus growth and husbandry (Anderson, 1997). Foods such as live fish, shrimp, clams, lobsters, snails and crabs are all good for octopuses and part of their natural diet and have been successfully fed to octopuses in captivity. Recently, one of us (RCA) experimented with a number of different novel foods for octopuses as enrichment with good success (Anderson, 2008). Food such as raw chicken (or other poultry) is taken by octopuses such as the giant Pacific octopus (GPO – *Enteroctopus dofleini*) but should not be given as a major portion of its diet. These foods can be used as a special treat, in emergencies, or as part of a regular enrichment program.

Captive octopuses do well on a regular diet of readily available aquarium food such as herring, capelin, anchovy, squid and fish fillets. These foods can often be collected locally or conveniently purchased in the seafood section of a local grocery store. This kind of diet requires little response from the octopuses and minimal handling time as the food is ready to eat. At the Seattle Aquarium we used such a diet to raise GPOs weighing several ounces to 60 pounds over a two to three year period. Such animals demonstrated all manner of normal behaviors. The growth of one of them ("the Dark Avenger") was monitored closely over four months, when it grew 2.7% of its body weight per day, indicating good growing conditions. Of course octopus growth is also dependent on temperature, species and size (Wood and O'Dor, 2000).

We use live crabs as a special treat for GPOs including public demonstrations of an octopus's ability to find and eat a crab, and as part of our tri-weekly enrichment program for octopuses. We buy live Dungeness crabs with 6-7 inch carapaces (shells) from a local seafood vendor. Such crabs are typically caught in the Pacific Ocean of Washington's coast or from northern Puget Sound. We can catch similar crabs locally but are reluctant to use them as food since they may have accumulated toxins from polluted local sediments (Anderson, 2003).

Our GPOs take an average of three hours to eat a crab. This can be accurately timed if an octopus is sitting on a vertical surface. By closely watching the octopus we can determine when an octopus drops the last shell piece and has finished feeding. Other natural foods such as fish and clams are typically consumed in much less time. This time can also be compared to their handling time of novel objects and subsequent marked habituation of only 30 seconds (Anderson and Leontieu, 2005). There is no habituation to these food items; they are always eagerly eaten.

An octopus such as a GPO does an extremely good job at cleaning and eating a crab (see photo). Almost every hard part of the crab is disjointed (literally), and the flesh is extracted from every piece, including the gills and the hepatopancreas on the underside of the carapace. The shells are rarely broken, just disjointed. Some crabs are drilled by some octopuses, either in the top of the carapace, in one of the sutures (joints) of the

crab. Other octopus species drill other places on a crab. The claws of some crab are drilled by the common octopus (*Octopus vulgaris*) and the horned octopuses of northern Europe (*Eledone cirrhosa*) drill into the eye of a crab (ouch!) to inject their venom (Grisley et al., 1996).

We used to think an octopus's radula did most of the drilling of the tiny hole but lately we have learned that an octopus's salivary papilla ("tongue") exudes a substance that softens and dissolves shell material. An octopus then injects a salivary venom that paralyzes and kills a crab and starts the digestive process (Nixon and Maconghie, 1988).

We have looked at the shell remains of many Dungeness crabs fed to GPOs with no drill holes, so the GPO either drills it somewhere we can't find or exudes venom for the crab to respire or ingest. In other species, a crab is drilled and injected in an average of 50 seconds, as evidenced by seeing the "fibrillation" (quivering of the legs) whence a crab is effectively killed by the venom (Halm, et al., 2000)) so the venom is very potent against crabs. We suspect that GPOs may inject these crabs through one of their joints, because all the muscle attachments and ligaments holding the joints together are loosened in the crab. The octopus thus has access to all the flesh, including the "lump meat" inside the crab's body skeleton and even inside the tiniest, pointed ends of the legs (the dactyls).

Thus the procedure for eating a crab appears to be: 1.) catch and subdue the crab physically (wrap it with arms and suckers, pin its claws to its body?), 2-3.) drill a hole into the flesh somewhere and spit it through the hole or at the mouth or respired water, 4.) wait for the crab to die or be paralyzed, 5.) separate all joints (dissolve ligaments and pull joints apart, 6.) remove and eat all flesh from shell parts, and 8,) discard shell parts. Such a progression accurately explains what we know of octopuses eating crabs and since this progression takes about three hours, we recommend strongly that presentation of live crabs occasionally or routinely be part of an enrichment program. Live crabs are routinely available at seafood markets in most cities nowadays, Blue crabs and lobsters are excellent substitute for Dungeness crabs as food for GPOs and will keep them occupied a similar amount of time, and live crayfish can also be used.

Enrichment programs for octopuses should include feeding of live natural food items such as crabs (Anderson and Wood, 2001). Enrichment items or programs should encourage the captive octopuses to perform natural behaviors such as searching the rocks for a hidden crab or opening a prey puzzle (Rehling, 2000), and then opening and eating the crab. As we discovered, eating a crab can take three hours, not including the time spent on finding or stalking it. This extended time can also fascinate the public watching a display octopus and can be used as an "interpretive moment" by staff to explain to the public what the octopus is doing. There are no other enrichments we know of that consistently engage an octopus so long in a natural behavior. Therefore we recommend the use of live crab enrichment feeding for captive octopuses.

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The remains of a red rock crab (*Cancer productus*) after being eaten by a GPO.
Photo by Margarite Hargrave of the Seattle Aquarium.

BZZZZZZ….

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A buzzing sound is synonymous with many annoyances in our humanistic world. From a bee around your head or that pesky mosquito in your ear, to those people who have their cell phones set to vibrate. A buzzing sound is usually not a sign of good things to come.

Recently, a buzzing noise has been heard stemming from a three syllable word. Can you guess what it is? Wait, I hear it, bzzz. Over there, bzzz. No, over there, bzzz. It is getting louder and louder, BZZZ. Surely I am not the only one hearing this frustrating noise. I try to swat it from my ear, bzzz, bzzz, bzzz. Now I hear it coming from all directions. Bzzz, bzzz, bzzz. All of a sudden, as if some military genius has coordinated this sneak attack, I am stung all at once from my head down to my toes. A sense of relief overwhelms me. If they are bees then they might die after the first sting. I look around for all of the dead bodies with a quiet smirk. Just as I see that there are no bodies, I hear that sound again. The sound is even louder and from even more directions. Why is no one else hearing this? Bzzz, bzzz, bzzz. I search for a fly swatter, a newspaper, a magazine. The only thing near me is a jar. I quickly unscrew the lid and attempt to capture one of these flying things. There are so many of them that catching one takes no time at all.

After sedating it, I examine it very closely and find that it appears to be a miniature person with wings. And something else. It is holding a sign with markings on it. Perhaps it is in a union? I increase the magnification of the microscope and see that the sign says 'ENRICHMENT, OR ELSE!!!' As I begin to remove the sign from its firm grip it awakes, flaps the sign, and flies away, bzzz. The foul stench left in the jar led me to believe that it was marking its new territory for yet another attack. The attacks continue during the subsequent days. I became very proficient at catching these things and preserving them in formaldehyde, rather than sedating them. I also found a new sign, 'ENRICHMENT IS GOOD!!!' The signs looked like this.

All of the signs were brief and contained few words. More frustratingly, the signs contained no explanation for the attacks or what enrichment had to do with anything. I called these flying things snarfgugglins. I wondered if these snarfgugglins were in politics, as they offered only catchy slogans but nothing of substance. I began to hear news from around the world that the invasion was not merely an isolated event but had spanned the globe. From pole to pole, hard-working individuals were being attacked over and over.

It seems like eons ago that snarfgugglins first made their impact. Since then, I have tried to understand how this fad has taken hold in so many places without any sort of quantification. What I found out may shock the very soul of that loveable octopus *enjoying* its Mr. Potato Head.

The roots of enrichment can be traced back to the 1920's scientist Robert Yerkes who worked with primates. He noted that the addition of toys to the sterile research cages of his subjects brought about new behaviors. He was correct. If I were to add a large rodent to the cage of a tiger only exposed to feeding dishes, I would expect to elicit some behavior from the tiger. Perhaps even a natural hunting behavior towards this live animal? It appears that these meager findings seemed to have been misinterpreted over the years. Apparently, all animals, no matter their captive environment, need enrichment.

This brings us to the present, where enrichment is preached at aquariums throughout the world with little evidence to back up such practices. While there have been exhaustive and discombobulated reports stating the need for enrichment, the exact reasons and modes of quantification seem to elude these documents. After researching the past and present history of enrichment, I set out to answer a few questions. At the end of this investigation, I was left stupefied as to why so many people supported a mere buzz word and at a loss as to how to suppress this fad.

The first question I asked myself was what enrichment actually was because there are so many different definitions which are articulate and flowery but ambiguous. For these purposes, and to simplify the many definitions, I will define enrichment as anything added to an animal's enclosure that elicits a response. This definition may seem vague but simplifies the other more complicated definitions. Using this definition, enrichment can be anything, as its proponents will attest to. A flip of a light switch. A quick feeding in the morning. A proper cleaning of a tank. No longer are these necessary husbandry practices, these activities are all enriching the animals in the tank. Had I missed something? What had I been doing all my life? Had I been enriching as a child when I thought I was giving the necessary care afforded to captive fish? I had long-lived fish that reproduced often. I believed I was doing a good job. Had I been enriching as an adult? *The term, husbandry, appears to have been replaced with enrichment!* Frantically, I ran to my dictionary searching for husbandry. In the 21st century, though, a search in the dictionary was done on a computer through the internet. H-U-S-B-A-N-D-R-Y-ENTER. To my relief, husbandry was still in the dictionary with a clear definition. Husbandry is the careful management of a resource through scientific breakthroughs. Agriculturists' and aqua-culturists' very livelihood depends on these advancements. I have worked on farms and in aquaculture facilities and never did I read a bedtime story to a pig, throw a ball to a salmon, or *play* with a cuttlefish. These animals were all thriving as a result of excellent husbandry practices, without any kind of enrichment.

My next focus turned to the application of enrichment in aquariums. I looked at two groups of animals to which I have extensive knowledge and first-hand observations: sharks and cephalopods. A common method of enrichment is said to be behavioral conditioning. Many animals in aquariums are subject to behavioral conditioning, for both good and bad reasons. Some are conditioned for routine veterinary procedures while others are conditioned for still unknown applications. I worked with brown sharks in order to condition them to feed at a location designated by a target. In a matter of days the sharks fed within inches of the target. Not only had I conditioned them, but in doing so *I had also taught them to read!* Apparently, I had also enriched them, as I was later informed. How? It would have been simple to prove that they could or could not read. To prove this point, I could have constructed another target and recorded their actions. But how could one say that the sharks were actually being enriched and this enrichment was a benefit to the shark? The answer is simple. You could not. The targets looked like this.

Cephalopods, primarily octopuses, may be the poster larva for the positive outcomes of enrichment. Unlike many of their marine counterparts, Giant Pacific octopuses have been subjected to a numerous studies aimed at enrichment quantification. Why are these same studies not performed on other marine animals? Giant Pacific octopuses have been given toys, puzzles, different types of food, and a myriad of additional things that apparently enrich the animals' captive lives. It seems strange that an animal whose own behavior is so alien to us, is all too often the only *proof* used for the benefits of enrichment. Personally, if I was given a burrito wrapped up in some sort of puzzle that I had to solve in order to eat, I would become increasingly agitated. Just give me the burrito!

Perhaps there is more to octopus enrichment. Giant Pacific octopuses are not the most exciting animal to the masses shuttled through the turnstiles. The addition of a live crab or food puzzle is often accompanied by large groups of spectators in delight. This is certainly pleasing to the crowd and even some of the staff, but how did this come to be called enrichment when it is difficult to quantify these claims? It is difficult to ascertain what people are thinking, but when an octopus reaches out for our hand we think it is happy and it is playing with us. Why? Maybe the octopus is becoming more aggressive and these enrichment sideshows are only making the staff and crowds happy. Even more startling, given the apparent high level of intelligence afforded to octopuses, perhaps the enrichment practices are actually sharpening their physical and mental skills so that they may wage an all-out attack on us humans and take back their oceans!

I had to pause and reflect upon these new thoughts. Was enrichment merely a buzz word used to please the public into thinking that these captive animals were actually happy? I re-examined all of my data. It appears that I missed something. The signs also had writing on the back of them. I collapsed.

I woke up thinking that I was out of this nightmare, but from a far off distance I could hear a subtle noise, bzzz…

General Information for RAW 2009:
23rd Regional Aquatics Workshop (20th Year)

Host Institution: Newport Aquarium: Newport, KY
(Directly across the Ohio River from Cincinnati, OH)

Tentative Schedule:

AZA Pre-RAW TAG, SSP, CAP and, AQIG meetings ..... June 8th
Jellyfish Symposium ..... June 9th
Icebreaker ..... June 9th
Main Conference (RAW Paper Sessions) ..... June 10th-12th
Post Conference Trip - TBD ..... June 13th

Where (Sessions and Main Hotel):

Radisson Hotel Cincinnati Riverfront
668 West Fifth Street , Covington, Kentucky 41011
Reservations**:** (888) 201-1718 US Toll Free
Telephone**:** (859) 491-1200 Fax**:** 859-491-8698
http://www.radisson.com/covingtonky
REMEMBER TO MENTION RAW 2009 WHEN BOOKING!

Budget:

Registration:
$50 / attendee if postmarked on or prior to April 1st, 2009
$85 / attendee if postmarked after April 1st, 2009

Room Rates:
At Radisson Hotel Cincinnati Riverfront: $119 / per night plus tax

Post Conference Trip:
~ $25 / attendee pre-conference booking*
~ $50 per attendee post / during-conference booking*
*Pricing is preliminary and to be used for budgeting purposes however it is subject to change by Newport Aquarium. We are diligently working to keep costs at the bare minimum.

Airport Options:

Airport Name	Drive Distance to Radisson
Cincinnati International Airport (CVG): Covington, KY	15 minutes (shuttle)
Dayton International Airport (DAY): Dayton, OH	45 minutes
Bluegrass Airport (LEX): Lexington, KY	60 minutes
Port Columbus International Airport (CMH): Columbus, OH	110 minutes
Louisville International Airport (SDF): Louisville, KY	115 minutes
Indianapolis International Airport (IND): Indianapolis, IN	120 minutes

Dear Industry Colleague,

Our largest, aquatic specific, annual conference, the Regional Aquatics Workshop (RAW) is being hosted in June 2009 by the Newport Aquarium, in Newport, KY…just across the Ohio River from Cincinnati, Ohio.

The purpose of our yearly conference, as you may already be aware, is to provide a forum for the presentation, discussion and dissemination of information detailing captive maintenance and husbandry practices in large-scale aquaria. Attendees of RAW include Aquarists, Curators, Life Support System Operators and Directors from large and small public aquariums and zoos all over North America, Europe, Australia and occasionally Asia and Africa.

With over 200 attendees expected, the diversity and worldwide representation provides an excellent forum to showcase and share your knowledge, challenges and questions with your fellow colleagues. The staff of the Newport Aquarium and the RAW advisory committee would like to cordially invite you to attend the 23rd Annual Regional Aquatics Workshop (RAW). RAW is not just another conference, it is an opportunity for the professional aquarist to grow, develop, learn, network and share ideas. Our small, but highly skilled community is consistently striving to improve its techniques and there is no better way to do get a pulse of what is going on in the industry than to attend RAW.

So mark you calendars, get those budgets in and please join us in June of 2009, at the Newport Aquarium…where there is always a million gallons of fun!

Sincerely,
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WHY AND HOW TO MAKE A PENGUIN WETSUIT

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Abstract

A 25 year old male African penguin, *Spheniscus demersus,* did not molt for four years resulting in exposed skin and down. Due to his lack of insulation, he was shivering, inactive and reclusive. After medical diagnostics were performed, cause for arrested molt not determined, and a hormonal treatment proved unsuccessful in inducing molt, the penguin was suited with a removable 3mm neoprene vest. The neoprene vest created a form fitting insulative layer that allowed full natural movement both in water and on land. While wearing the neoprene vest the shivering behavior subsided, normal activity resumed and he engaged in normal social behaviors. This paper describes the wetsuit design and provides patterns for making the vest that may be functional for a penguin in similar condition.

Introduction

Penguins have internal biological clocks which cue molting and are influenced by exposure to external environmental factors (Cockrem, 1990; Cockrem, 1995; Davis, 1995; Davis and Renner, 2003, Wallace and Walsh, 2003). African penguins *Spheniscus demersus* molt approximately every 10.5 months, resulting in complete replacement of feathers (Cooper, 1978; Bennet, 1990). Indications of a penguin molting include appetite increase, significant weight gain (31%) and reduction of activity and displays (Bennet, 1990; Cooper, 1998). In wild and captive penguin colonies, irregular molt patterns can occur and have been attributed to inadequate pre-molt body mass (Cooper, 1978), behavioral, environmental or medical reasons. Penguins' plumage has responded positively through molt induction via use of several different drug therapies (Hines et al, 1993; Reidarson, McBain & Denton, 1999).

Case History

An African penguin hereafter referred to as "Pierre" was transferred to Steinhart Aquarium from The Maryland Zoo in Baltimore in June 1983 and has since resided at Steinhart Aquarium facilities. He is normally a dominant male with few health issues except a periodic cough since 1997. A workup in April 2000 diagnosed the cause of cough as inflammation of the upper respiratory tract with an allergic etiology. This resulted in treatment with Hydroxyzine at maintenance dosing ranging from 5 mg once daily to 10 mg twice daily to control cough. From May 2004 until May 2008, Steinhart Aquarium housed Pierre with the colony of African penguins in an exhibit described by Schaller (2006).

While located in this exhibit, Pierre molted in June 2004, replacing all feathers normally. However, since 2004, he did not show any usual signs of molting. As time progressed his feather coat became thin, down was exposed and bald patches around his chest, head and lower back appeared (Figures 1-3). His behavior changed and he did not socialize or frequently swim with the colony.



Figures 1, 2, & 3. Pierre, 2 February 2008

In February 2007 a feather loss workup was done. The complete blood count showed no indication of infection, chemistries showed a low grade kidney dysfunction. Feather biopsies were performed and results found within normal limits. A treatment of 0.2mg Levothyroxine twice daily for 45 days was prescribed and followed (Hines et al, 1993). This treatment did not induce molt in Pierre's case. The staff tried a variety of alternative methods, including time in the Sun Pen for exposure to higher levels of UV and adding heat lamps to the exhibit. All alternative methods proved ineffective.

In January 2008, with help from Celeste Argel a seamstress who had experience in tailoring children's costumes, a neoprene vest was developed that allowed the penguin full movement of head, wing, and torso. There were many fittings, requiring both biologist and seamstress to tailor the vest for conformed contour. These fittings included time spent both on and off exhibit to determine color, type and thickness of material, shape of suit, wing hole size and vest closure.

Materials and Methods

The colors tested included white, brown and black. Other penguins seemed interested in all colored vests with black drawing the least attention. Neoprene was chosen for flexibility of movement and warmth while wet or dry. The thickness of 3mm was chosen as a pliable thickness, allowing for safe motion, and keeping the penguin slightly positively buoyant. Small wing holes maximized insulation without causing irritation.

The Velcro vest closure was placed along the entire length of the suit for easy donning and doffing. This also accommodated for any weight fluctuations. The Velcro loop side was sewn onto the neoprene facing away from the penguin's body. This placement allowed the penguin to rub its head against neck and back without irritation to head or eyes. Seams were positioned on the penguin's sides to avoid irritation while at rest. Unstitched neoprene edges on the neck, wing and torso were chosen to prevent skin abrasions or raw marks at those crucial borders (Figure 4-6).



Figures 4, 5, & 6. Pierre, 23 February 2008

A vest design with exposed torso took into consideration the following penguin movements and behaviors: standing, walking, running, laying down, swimming, stretching, feeding, drinking, braying, preening, allopreening, excreting waste and copulating. Incubation and chick rearing were not observed during trial. The vest design allowed staff to check when molt begins as tail feathers are first to grow in. The staff monitored all phases of design and function. The trials were performed off exhibit then on exhibit for increasingly longer periods of time.

Discussion and recommendations

Penguins are highly social and a hierarchy is maintained through head movement, stance of beak, body posture and eye position (Eggleton and Siegfried, 1979). The wetsuit does not obscure those behaviors. However, it initially draws concentrated attention from cohorts to the wearer. The suited penguin must be experienced in effectively defending itself against potentially aggressive behaviors. In addition, the bird must be capable of handling the stress of capture and restraint for fittings.

In April 2008 Pierre completely grew his feathers in after 6 weeks of wearing the vest (Figures 7-9). One hypothesis for the molt was that Pierre was inefficiently utilizing calories due to lack of feathers and while wearing the vest the conservation of energy may have contributed to molt. However, two months prior to wetsuit trial and subsequent molt, Pierre was taken off the Hydroxyzine. This was to evaluate whether the drug was a factor in his arrested molt. Since April 2001, Pierre had been on a course of 5-10 mg Hydroxyzine. Over the years he had been taken off treatment for as long as six months to verify effectiveness. Though he had not molted when off medication in the past, he also did not have previous molt problems. It is impossible to rule out that discontinuation during trial caused molt. Note, as of the end of April 2008, Pierre was placed back on Hydroxyzine 7.5 mg twice daily to control the increase in his cough frequency.

It is difficult at this time without additional analysis to determine what caused his molt since the normal molt process is a result of many contributing factors. On the other hand, the vest fulfilled the goal of comfort and insulation. The vest was fundamentally a replacement for worn feathers and bald patches. The application was particularly useful to this penguin as he was thin (3.052 Kg), and it may not be useful to a bird with a thicker fat layer that can maintain its body temperature.



Figures 7, 8, & 9. Pierre 5, June 2008

There are cautions for a penguin wearing a wetsuit. The initial suit made from neoprene was too large for Pierre. He was able to get his foot completely into the wing hole while scratching and was trapped. The suit was removed, cut and re-glued to securely fit and reduce the wing holes' diameter. The other danger observed was an initially well intentioned tab sewn into the suit by the neoprene seamstress. These tabs are normal for wetsuits and aid in removal. Unfortunately the tab was sewn to form a loop. The penguin, while preening, caught its beak in the tab. Although the tab was useful, it was crucial to attach with only one piece of cloth or sewn so no loop is created. A potential danger that is inherent in naturalistic exhibits is neoprene can catch onto rockwork or concrete. We did not have these materials in the exhibit at the time therefore did not experience this hazard. It is highly recommended to evaluate the exhibit and monitor the bird extensively while it is wearing the vest.

How to Make a Penguin Wetsuit

Patterns (As submitted they are actual size)

- Print the following 3 patterns onto rigid paper and cut along solid lines
- Front (chest) Pattern may be too wide for printing margins, if printing cuts off parts of side, the curved edge of Back Patterns can be traced onto sides of Front Pattern to make up for printing loss.
- Triangular cutouts are for the wings
- Patterns can be adjusted to penguin size by increasing printing size
- Instruction side of Front pattern will be towards penguin body
- Instruction sides of Left and Right Back will face away from penguin body

Measurements and Neoprene Properties

- Measure circumferences of the penguin neck, chest by wings and hips.
- Measure lengths of neck to hips on front side of body and on back.
- Add at least 2 inches to circumference to allow for the Left and Right Back Pattern to overlap for the Velcro closure on the back.
- Neoprene patterns are smaller than cloth patterns, so after measurement, reduce the total measured lengths by 1 inch.
- Neoprene is easier to cut and refit than to add to. The patterns can be made slightly larger to begin with then trim the neoprene suit after fitting (see caution under Discussion and Recommendations).

Materials List

- Wetsuit material; at least 3 square feet per vest of black 3mm neoprene
    - http://www.seattlefabrics.com/neoprene.html#2mm%20and%203mm%20Neoprene
- Neoprene glue
- 10 inches of 2 inch wide black Velcro "hook side"
- 20 inches of 1 ½ inch wide black Velcro "loop side"
- Straight pins
- Black thread
- Scissors
- Neoprene sewing machine/needle
- Neoprene seamstress or local dive/surf shop that makes custom or standard wetsuits

Manufacture Vest

- Front Pattern is for front (chest) of penguin
- Left and Right Back Patterns are made separately with Velcro enclosure on the back
- Seams are on side of penguin, they are to be glued and sewn closed. If able, glue only on the first fitting, in case the suit needs to be taken in.
- Left and Right Back pieces are attached to the Front piece on their curved edges by glue/sewing, they over lap each other on their flat side.
- Two strips (8-9 inches long) of 1 ½ inch wide Velcro (loop) are sewn to the upper face (away from penguin body) of the Left Back piece along the straight edge of the neoprene.
- One strip (8-9 inches long) of 2 inch wide Velcro (hook) is sewn to the inside face (towards penguin body) of the Right Back piece along the straight edge of the neoprene.
- In order to remove the wetsuit more easily a tab (not a loop) can be added near the neck. Attach by sewing the tab between the hook Velcro and the neoprene on the Right Back piece (see caution under Discussions and Recommendations).

Suiting and Fitting Penguin

- This is a 2 person job.
- One person restrains the penguin.
- One person stretches one wing hole over first wing, stretches front of suit over chest. They than fold and place second wing into other wing hole and velcro the suit shut.
- Fitting includes monitoring all activities of the penguin while in the suit.
- The wetsuit should be evaluated if/where the gaps can be taken in.

Re-sizing

- If vest needs to be taken in it should be at the side seams equally.
- Seams can be cut with scissors.
- Straight pins are used to hold seams together while glue dries.

Acknowledgments

Thanks to Dr. Freeland Dunker. Pierre's positive response surprised us and he did not say "no" to my penguin wetsuit idea immediately, he asked "how?" Special thanks to Celeste Argel, who when I asked to help me make a penguin wetsuit did not walk away shaking her head at me as though I was crazy. Celeste

offered her unique skills and took on a project that taught both of us many lessons. The patterns are a result of many hours of thought, diligence and creativity that we saw provided comfort for an old bird. Also a special thanks to Oceanic Worldwide, who was kind enough to initially sew and glue the suit for us, as neoprene is a difficult material to work with. The final patterns are a result of me crawling around behind old Pierre, mentally taking notes so I could cut, glue and pin the seams together later that day for a fitting the next (affectionately called the Frankensuit while drying).

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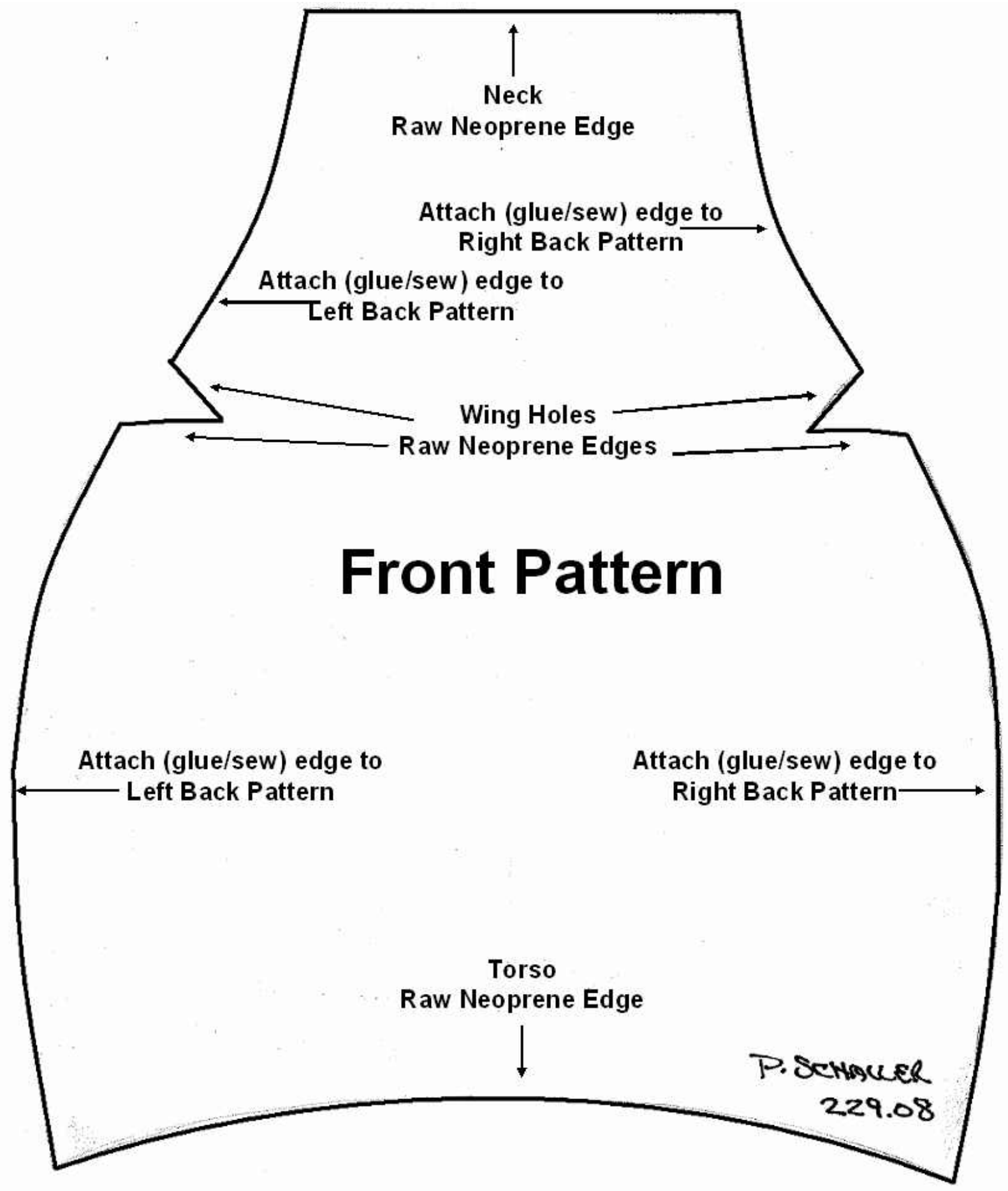
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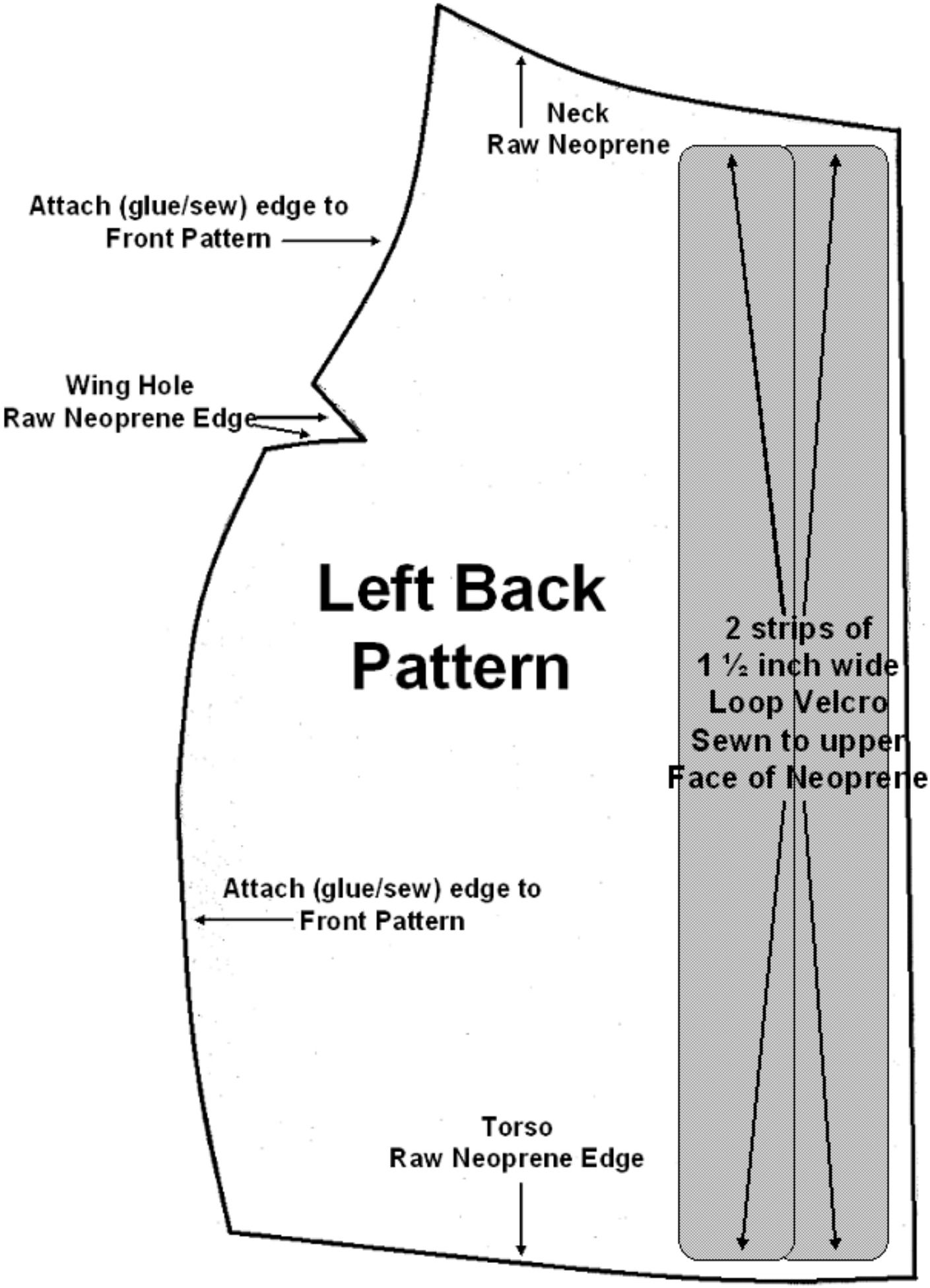
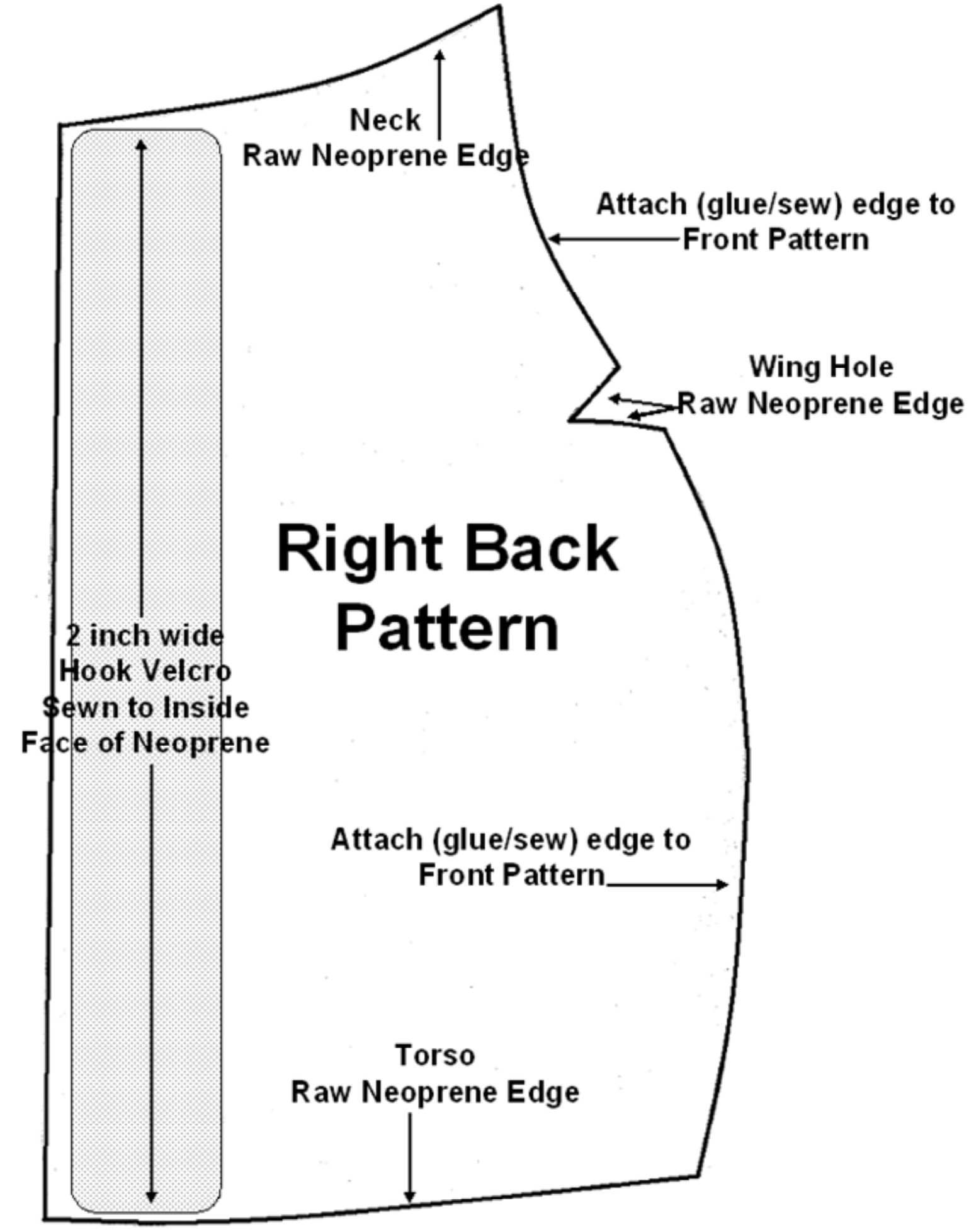
Raw Neoprene Edge
Attach (glue/sew) edge to
Right Back Pattern
Attach (glue/sew) edge to
Left Back Pattern
Wing Holes
Raw Neoprene Edges
Front Pattern
Attach (glue/sew) edge to
Left Back Pattern
Attach (glue/sew) edge to
Right Back Pattern
Torso
Raw Neoprene Edge
P. SCHALLER
229.08


Neck
Raw Neoprene
Attach (glue/sew) edge to
Front Pattern
Wing Hole
Raw Neoprene Edge
Left Back
Pattern
2 strips of
1 ½ inch wide
Loop Velcro
Sewn to upper
Face of Neoprene
Attach (glue/sew) edge to
Front Pattern
Torso
Raw Neoprene Edge


Neck
Raw Neoprene Edge
Attach (glue/sew) edge to
Front Pattern
Wing Hole
Raw Neoprene Edge
Right Back
Pattern
2 inch wide
Hook Velcro
Sewn to Inside
Face of Neoprene
Attach (glue/sew) edge to
Front Pattern
Torso
Raw Neoprene Edge

OBSERVATIONS ON THE REPRODUCTION OF ATLANTIC BLACKTIP SHARKS *(CARCHARHINUS LIMBATUS)* IN CAPTIVITY

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Introduction

Blacktip sharks (*Carcharhinus limbatus*) are a species of shark found throughout the oceans of the world. The blacktip is considered to be a commercially important shark, and can also be found in several public aquariums throughout the United States as an exhibit animal. The Albuquerque Aquarium currently has five blacktip sharks on display in its Shark Tank. Mating behavior has been observed amongst the individuals of this group, and one female recently gave birth to a litter of pups. Pups were physically retrieved by two staff divers and several aquarists stationed at the top of the tank from the exhibit during parturition. This paper details the observations made by staff and volunteers prior to and during the birth of the blacktips.

Blacktip Natural History

The Blacktip shark (*Carcharhinus limbatus*) is a species of elasmobranch found worldwide in tropical oceans. Keeney and Heist (2006) identified two genetically distinct populations of blacktips: one group resides along the western Atlantic Ocean/East coast of the United States, the other in the eastern Atlantic and Mediterranean to the Pacific and Indian Oceans, including Japan, Hawaii and the Philippines, and as far south as South Africa.

Castro (1996) and Killam (1987) observed details about the natural history of the blacktip sharks of the western Atlantic Ocean. Blacktips are a viviparous species of shark that utilize a placental method of embryo development. Age at maturity for most blacktips is 6-7 years for females and 4-5 years for males. The reproductive cycle of the blacktip shark is biennial, consisting of a gravid year and a subsequent "year off" for the females to rest and recover. Mating occurs in May, June and July, and females have a 10-11 month gestation period. Young at birth measure approximately 50-60 cm and weigh approximately 1 kg. Young remain in shallow water nursery areas until the fall season. Killam (1987) noted that sex ratios for embryos were approximately 1:1, while Capape (2004) noted that newborn males slightly outnumber females in populations off South Africa. Heupel and Simpendorfer (2002) conducted a study to determine the mortality rates among juvenile blacktips over a period of three years. They determined that most natural and human-related shark mortality for blacktips occurred within the first 15 weeks of life: those that survived migrated southward from nursery areas in Florida in the fall months.

History of the Blacktips at Albuquerque Aquarium

Blacktip sharks were collected from the Gulf of Mexico for the Albuquerque Aquarium in 1998. They were brought into the facility as juveniles and were grown up to adulthood at the aquarium. Sharks at the aquarium are not named, instead they are assigned numbers. Currently, there are five sharks – three females (numbers 1, 2, and 5) and two males (numbers 3 and 4). Since 2006, mating behavior has been observed by aquarists amongst several of the sharks and breeding scars have been noted on all the females. However, only one female has brought pups to term. The following is a list of the observations made of all three females in the tank.

#1 Blacktip (female)

Breeding marks were observed on this female in 2006, 2007 and 2008. Mating was observed between Number One and male Number Three in January of 2008. However, this female has not undergone any noticeable weight gain or loss, no noticeable change in feeding behavior, and pups have never been retrieved or observed from this female. It is believed amongst the staff that she is not carrying pups to term or is storing sperm for later birth.

#5 Blacktip (female)

This female, smaller than the other two, has not exhibited any noticeable weight loss or gain, and hasn't exhibited any fasting behavior. Mating has never been observed with this female and any of the two males. However, in February and April of 2007, Number Five exhibited several mating scars on her body and pectoral fins.

#2 Blacktip (female)

This shark is approximately ten years old and has had three observed pregnancies. Breeding marks have been frequently observed on this female. In February of 2006, Number Two stopped eating for a period of ten feedings. The shark had undergone significant weight gain in the months prior to the fasting, and in March of 2006, lost a significant amount of weight overnight.

The following year, the shark once again gained a significant amount of weight in the months following March of 2006. In January of 2007, Number Two stopped eating for a period of six feedings. In February of 2007, Number Two once again lost a significant amount of weight overnight and subsequently exhibited breeding "bite scars" on her pectoral fins and body. Bite scars continued to appear through April of 2007.

Following this weight loss, the shark once again gained a significant amount of weight. In January of 2008, Number Two stopped eating again for a period of six feedings. After the third skipped feeding, aquarium staff were placed on 24-hour watch to look for signs of pup delivery. On January 19, 2008, aquarium staff observed Number Two give birth to five pups, one of whom was eaten by a sandbar shark (*Carcharhinus plumbeus*). The other four were removed by divers and taken to a holding pool for safety. After looking at the observations of birth and weight loss, it is believed that this female has a trend of giving birth once a year. This trend is in contrast to the findings of Castro (1996) of blacktips in the wild, which have a biennial reproductive cycle with a "year off" to rest.

Pre-parturition observations

Prior to the birth of the pups, aquarium management and staff examined the different alternatives available to successfully retrieve pups. Numerous suggestions had been made, including moving the mother out of the main exhibit and placing her in a holding pool. The decision was made to have the mother placed on 24-hour watch, and during the beginning of the birthing process, have the observer call backup staff. Upon arrival of staff, pups would be retrieved by divers stationed in the tank along with aquarists stationed at the top with nets. This way, the mother would not abort the pups due to a stressful physical transfer out of the main system. Observations of the pregnant female began on January 12. From previous birth and pup loss observations, the delivery date was expected to be March 8. However, the female gave birth to pups much earlier than expected, on January 19th of 2008.

Figure 1. Pregnant Blacktip (Number Two)

During the week prior to birth, the female was actively pursued by the males during the overnight hours. Both males attempted several times to mate with Number Two while she was still pregnant.

It was also noted that the female's cloaca would open at random intervals during the week prior to birth. Beginning on January 13, Number Two's cloaca would open for a minute and re-shut. During the times that the cloaca would open, the female's anal fins and side muscles would twitch. The males would also follow her around and attempt to mate with her. As the days passed closer to the birth date, the cloaca would open for longer and longer periods of time: on the 16th of January, an aquarist noted that the cloaca was open for a full five minutes before it shut.

The pregnant female was off feed in the weeks prior to the birth. Aquarists in the years prior to the birth noted that the female went off feed one to two weeks prior to the birth. However, on January 17, two days before the birth, she ate a French Grunt at approximately 12 a.m.

The female's pregnancy "bulge" was noted by an aquarist on January 14 to be thickest in the center of the body, closest to the shark's pectoral fins. On January 17, two days before the birth, the aquarist on duty noted that within a 30 minute time span, the entire pregnancy bulge had shifted from the center of the body to the posterior portion, closer to the anal fin. The area of the belly where the pregnancy bulge had been also showed some dark patches on the skin of the fish.

Noticeable placenta-like material was observed floating in the tank one week prior to the birth. The placenta was clear, looked like plastic, and was netted out by staff.

Observations during parturition

Number Two started birth at 6:55 p.m. on January 19, 2008. The main tank lights were kept off to keep the birthing process as natural as possible for the shark – the lights were not to be turned on until backup staff arrived. The aquarist on duty first observed massive activity in the tank by several other species: sandbar

sharks (*Carcharhinus plumbeus*), other blacktips, tarpon, and barracuda. These species increased their swimming speeds and normal swim patterns appeared disrupted. The two sandtigers (*Carcharhias taurus*), nurse sharks (*Ginglymostoma cirratum*), turtles and drum did not seem to respond. The aquarist observed a small caudal fin sticking out of the cloaca of the shark. Other aquarists were called for backup, and the aquarist attempted to net the pup out of the water from the top. Pup #1 was born near the surface of the tank (belly down) opposite of the aquarist's position at the top of the tank. The pup could not be retrieved, and was eaten by one of the tank's sandbar sharks. The female swam in rapid circles around the tank, and as she expelled each pup, she twitched her anal fins, her abdominal muscles contracted violently, and she shook her tail fin rapidly back and forth.

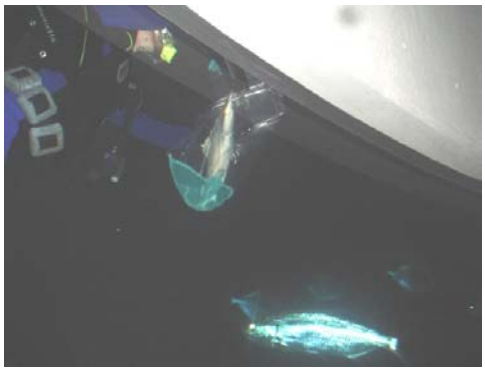
Figure 2. Female giving birth

During the period from 7:00 to 7:30, the aquarist continued to call other aquarists for backup and tried to follow the movements of the birthing shark in the darkened tank. It is believed that a second or even a third pup was born and consumed during this time period, since the birth time between most of the pups was about fifteen minutes (with the exception of the third and the fourth). Since no birth or predation was observed by the aquarist, these pups were not counted in the final total.

At approximately 7:30 p.m., additional aquarists arrived, and two divers entered the water to retrieve the remaining pups. Lights were turned on to facilitate pup retrieval and for the purposes of dive safety. When the lights came on, tank activity by the sandbars, tarpon and barracuda went back to "normal".

At 8:00 p.m., Pup #2 was born (belly down) and retrieved by aquarists stationed at the top of the tank. The pup was taken to the shark tank acclimation pool and sequestered from the tank predators.

Pups 3 and 4 had both of their tail fins protruding from the mother at the same time. There was concern that the babies would be stuck in the mother and she would not be able to give birth to them. However, Pup #3 was born at approximately 8:15 p.m. (belly down), and was netted by divers. Pup #4 was born at 8:19 p.m. (belly down) and was netted out by divers.



Figures 3 and 4. In-Tank Shark Pup Retrieval

Pup #5 was born at approximately 8:28 p.m. This pup was born belly up, in contrast to the other pups born. The pup was netted out of the tank by aquarists stationed at the top of the tank, and was almost eaten by a barracuda who had taken interest in the tank activities. This pup also did not swim immediately: it almost seemed stillborn and seemed to fall or sink down in the water column. When swimming finally occurred, it swam very erratically and took a long time to adjust to its surroundings.

A few side notes about the birth: placenta-like material, brown in color, was found in the tank after the birth. It was similar to the white material found a week earlier, and appeared as a plastic-type of material. Also, the pregnant female's swim pattern changed drastically during parturition: it appeared that she chose to swim around forms in the tank during the birth. It is believed she was exhibiting this behavior in an attempt to find a secure area to drop the pups, away from predators.

Additionally, several short camera videos were taken of the female giving birth. Please contact Holly Casman (HCasman@cabq.gov), Aquarium Manager at the Albuquerque Aquarium for further access to the videos.

Post-birth neonatal observations

Three of the pups swam erratically for approximately one hour after the birth. The fourth (born belly up) took about two hours to recover. One pup ate a small piece of mackerel one and a half hours after being born. The surviving pups were numbered Six, Seven, Eight and Nine to differentiate from each other and from the other blacktips.

The pups were not weighed and measured until sixteen days after the birth. Staff were concerned that any physical trauma or stressful measuring/weighing techniques would be detrimental to the development of the pups. The following is a list of weights and measurements for each pup retrieved.

Blacktip	Sex	Length (fork)	Length (total)	Weight
#6	F	53.3 cm	66.0 cm	1.90 kg
#7	F	53.3 cm	68.6 cm	1.95 kg
#8	F	50.8 cm	60.9 cm	1.70 kg
#9	M	50.8 cm	63.5 cm	1.50 kg

Figures 5 and 6. Blacktip Pups in Holding Pool

Approximately one month after the birth, the pups were put on display at the Albuquerque Aquarium in the Shallows and Shores exhibit. They were kept on exhibit throughout the summer of 2008, when they were taken to a behind the scenes holding area for grow-out.

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INVESTIGATIONS INTO THE NUTRITIONAL COMPOSITION OF MOON JELLYFISH, *AURELIA AURITA*

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Abstract

Proximate nutrient, fat-soluble vitamins A and E, and mineral composition of the moon jellyfish, *Aurelia aurita,* was measured in wild specimens from Jamaica Bay, NY, and in captive cultured specimens from the New York Aquarium. Crude protein content of free-ranging jellyfish was approximately twice that seen in captive animals (9.20% ± 0.40% dry matter (DM) versus 4.95% ± 0.20%); conversely, fat content of cultured jellyfish was about twice that of wild animals (5.16% ± 1.00% and 2.05% ± 0.37% DM, respectively). The cultured *A. aurita* in this study had higher fat levels than any other reported to date in the literature for this species. Wild *A. aurita* contained significantly less vitamin E than did cultured counterparts (9.8 ± 4.8 IU/kg vs. 51.4 ± 16.5 IU/kg DM), likely a function of captive dietary enrichment. Mineral composition also varied widely between wild and captive jellyfish. Wild *A. aurita* contained 1420 ± 160 mg/kg phosphorous (P), 55.3 ± 3.1 mg/kg iron (Fe), and 17.9 ± 0.1 mg/kg zinc (Zn), whereas captive cultured *A. aurita* contained 2870 ± 80 mg/kg P, 119 ± 2 mg/kg Fe, and 72.8 ± 2.5 mg/kg Zn. Physical differences between wild and captive specimens were also found. In order to assist in understanding possible links to differences in body composition, proximate nutrient and mineral content of the captive diet was also analyzed and is reported. Information obtained from this study may assist in development of more effective dietary husbandry guidelines for captive jellyfish. Additionally, nutrient/mineral composition of jellyfish and other coelenterates may be a useful indicator of water quality and habitat suitability, as well as useful in applied feeding management of sea turtles, for which jellyfish are a primary food source.

Introduction

Since the first applications of zoo nutrition, the field has focused extensively on mammal, avian, and piscine species. Less work, however, has been done on the nutritional needs of invertebrate species held in zoos and aquaria. It is therefore crucial that the nutritional needs of invertebrates be investigated.

Aurelia aurita, the moon jellyfish, is one such organism that is commonly housed in aquaria, and for which nutritional data remain sparse. Several marine biologists, including Lucas[19], Anninskiy[2], and Larson[16] have studied the proximate composition of *A. aurita.* Fukuda and Naganuma[9] investigated fatty acid composition and Lane et al.[18], Shick[22], and others studied amino acid concentrations. Spangenberg[25], and Lucas[18] have observed *A. aurita* growth under controlled conditions. However, while *Aurelia sp.* is one of the most commonly studied scyphozoans, as seen in Arai[4], in comparison with mammals, information regarding the nutritional needs and composition of *Aurelia sp.* is still somewhat lacking.

Dawson and Jacobs[8] report that *A. aurita* is the scyphozoan most commonly housed in aquaria. The frequency with which *Aurelia sp.* is held in captivity is likely due to a number of factors, including a large range and the fact that they are a cold water, nonzooxanthellated species. *A. aurita* has been found to inhabit coastal waters from 50°N to 50°S, with various sub- or sibling species likely throughout the region[8]. The

species or subspecies of *A. aurita* described by Dawson and Jacobs[8] as occurring in the Northeast Atlantic, including the species studied in this investigation, has also been found by Schroth et al.[24] off the coast of Norway, Iceland, England, and Germany, as well as in the Black Sea. Sibling species can be found throughout various other waters.

As a scyphozoan, *Aurelia sp.* exhibits a biphasic life cycle containing both polyp and medusae stages. While the polyp stage is clearly important in culturing the species, it will not be discussed in this paper. This paper discusses only the medusae, a bell-shaped form containing epidermis, gastrodermis, and relatively thick mesoglea[4]. Immediately prior to the medusa stage, *A. aurita* may be considered to be in the ephyra stage, which is an intermediate between the two forms (or possibly simply a small medusa). In various cnidarians the mesoglea has been found to contain a protein matrix [23] that serves a major role in muscle contraction[3].

Based upon analyses of gut contents, *A. aurita* medusae have been determined to be opportunistic zooplankton feeders[14]. Various studies suggest that feeding occurs primarily on copepods, with fish larvae, barnacle larvae, and a variety of microorganisms as other food sources. Prey selection appears to be related to medusa size, with umbrella diameter positively correlated to the number of prey and number of types of prey found in the gut[10,20,26]. The diet of any organism provides energy as well as some of the molecules used in order to survive, and the proximate composition of an organism is thus closely related to its diet[21]. In this respect, *Aurelia sp.* appears to be no different from any other animal. Fukuda and Naganuma[9] report that the fatty acid composition of *A. aurita* clearly reflects its diet.

Past investigations have examined the chemical and nutritional composition of *A. aurita*, yet these relationships need to be further investigated. The goal of this project was to examine and compare the nutrient composition of wild and captive New York Aquarium (NYA)-cultured *Aurelia aurita.* Many aquaria follow the same general procedure in terms of feeding and housing their jellyfish specimens, and thus the outcome of this study will be applicable to more than one institution. In the future, these data can be used to suggest test diets that may lead to better health of aquaria reared *Aurelia sp.* as well as increased cost-effectiveness for aquaria. This project thus also examines the nutrient composition of the diet fed to aquarium-reared jellyfish.

The data obtained in this investigation are likely to be useful in other arenas as well. As jellyfish can only obtain nutrients from the water in which the live, the minerals and mineral levels found in *A. aurita* may be indicative of the overall water quality in their locales. Furthermore, since *A. aurita* and other jellyfish are often eaten by sea turtles, the nutritional data obtained in this study may provide insight into sea turtle nutrition.

Methods

Sample collection

Wild A. aurita medusae between 5 and 12 cm in umbrella diameter were collected from a boat in Gerritson Creek, New York. Gerritson Creek, as part of Jamaica Bay located off of Brooklyn, NY, receives water from the Atlantic Ocean as well as effluent from the John F. Kennedy Airport and the Metropolitan Water Authority. Gerritson Creek also contains considerable marine debris.

Medusae were visually identified and captured in one-day trip in June 2003. Collection occurred on an incoming tide from surface water with a salinity of 16.5 ppt and a temperature of 19°C. Medusae between 8 and 12 cm in umbrella diameter were collected (n = 40, mean diameter (± SD) = 8 ± 2 cm) via netting of

surface water. After capture, jellyfish were placed in a bucket of sea water until all were collected. The medusae were then measured for umbrella diameter and placed into individual plastic bags in an ice chest. Upon return to the lab, medusae were rinsed off in sea water (from the intake pipeline discussed below) to remove excess salt, blotted dry on a plastic tray to remove excess water, and weighed. Samples were then replaced in plastic bags and put in a subzero freezer for approximately one day. Frozen wild *Aurelia sp.* were then combined into three groups, hereafter known as samples, pooled weights were 216, 380, and 254 g, respectively.

Captive *A. aurita* medusae between 5 and 10 cm in umbrella diameter (n = 43, mean (± SD) = 6.5 ± 1 cm) were obtained from the NYA's jellyfish cultures. This culture originated from a strand that was wild-caught offshore of Brooklyn, NY, during 2002, and was propagated at the Aquarium. Medusae were obtained from a closed kreisel sytem with a relatively constant salinity of 32 ppt and a relatively constant temperature of 16°C. Water changes of approximately 10% of tank water occurred weekly, with input water from an intake pipeline approximately 4.5 m deep and 60 m offshore from Coney Island, NY.

Jellyfish were removed from the kreisel via net and were placed in a bucket of water taken from the kreisel. Individuals were then rinsed in this water and blotted against a plastic tray to remove excess water. Umbrella diameter was then measured and the jellyfish were weighed. Individual jellyfish were placed into individual plastic bags and placed in a subzero freezer for approximately one day. Captive jellyfish were then combined into two sample groups (hereafter known as samples) with pooled weights of 330 and 230 g, respectively.

Diets and Diet Sample Preparation

Diets were prepared according to the manner in which NYA-cultured jellyfish are fed. This diet includes Super Selco®- (Artemia Systems, Inc, Baasrode, Belgium) enriched *Artemia salina* fed to *Aurelia sp.* once or twice daily, Cyclop-eeze (Argent Labs, Redmond WA, USA) fed to growing *Aurelia sp*. once daily, and a mixture of various foods (including clam and capelin) fed twice weekly.

Brine shrimp, *A. salina*, were enriched with Super Selco®, a nutritional supplement, according to NYA procedure. Decapsulation was completed by Aquarium staff members: 425 grams of Salt Creek Select Brine Shrimp Eggs (Salt Creek, Inc., Salt Lake City, UT, USA) were mixed with 32g of NaOH and then placed in a solution containing 1000 mL Cl_2 and 500 mL distilled H_2O. The brine shrimp were then rinsed in tap water until the chlorine smell dissipated. One and one quarter cups, approximately 265g, of decapsulated cysts were placed in 50 liters of sea water from the intake pipeline in a cylindrical polyvinylchloride (PVC) tank to hatch. The tank temperature was heated to 26.6°C and an oxygen line was placed in the tank to allow aeration. After 24 hours, casings and unhatched cysts were drained from the bottom of the tank and hatched *A. salina* were washed in salt water from the intake pipeline. *A. salina* were then enriched with Super Selco® according to Aquarium procedure and Woods, 2003 (0.6g Super Selco®/liter). Thirty-one grams of Super Selco® were emulsified in a Waring blender for three minutes and placed in 50 L sea water from the intake pipeline in the cylindrical PVC tank. After 24 hours, *A. salina* were removed and drained into a net. Excess water was squeezed out, and the 254 g sample was frozen in a subzero freezer for 24 hours.

One hundred fifty-seven grams of Cyclop-eeze® were obtained from a 400 gram frozen case. This sample was placed in a subzero freezer for 24 hours.

A mix of capelin (*Mallotus villosus*), clam (unknown spp.), and mysis (*Mysis relictica*) was prepared according to Aquarium procedure. Three female capelin with roe, weighing 15.7, 14.2, and 16.2 g, were obtained from a commercially prepared lot of North Atlantic capelin from Great Atlantic Seafood Co, Inc., (Portland, ME, USA). One clam from the New York area of the Atlantic Ocean, weighing 27.7 g, was obtained from a frozen pallet of clam from Doxsee Sea Clam Co, Inc. (Point Lookout, NY, USA). Twenty-eight grams of frozen *M. reticulata* were obtained from a 1.134 kg block from Piscine Energetics (Enderbery, BC, Canada).

The capelin, clam, and mysis were placed in a blender until homogenized. This sample is hereafter known as the "capelin mix." The weights of capelin, clam, and mysis used in this study are meant to be representative of what is used at the Aquarium, as there are day-to-day variations.

Nutritional Analysis

Frozen samples were partially thawed and ground using a food processor in the Bronx Zoo Nutrition Laboratory, Bronx, NY. Vitamins A and E extraction and analysis of wet tissues followed previously cited methods for meat samples[7]. Remaining samples (wild *A. aurita*, captive *A. aurita*, Super Selco® enriched *A. salina*, Cyclop-eeze®, and capelin mix) were freeze-dried for three days; sample weight before and after freeze-drying was recorded to determine water content. All methods of proximate analysis (crude protein, crude fat, ash) were the same for the various samples, according to standardized laboratory procedures for meat samples[1]. Macro- and trace minerals were assayed via inductively coupled plasma-mass spectrometry or atomic absorption (Se only) at the Laboratory for Large Animal Pathology and Toxicology (University of Pennsylvania, Kennett Square, PA).

Statistical Analysis

A least squares regression of diameter vs. mass of individual wild and captive *A. aurita* was performed using SPSS 11.5 for Windows. B_0, b_1, R-squared, and standard error values were found for both data sets. ANOVA F-tests were performed to determine statistical significance between populations. SPSS 11.5 for Windows was also used to examine differences in crude protein, fat, ash, vitamin A and vitamin E activity of wild vs. captive *Aurelia sp.* samples. Mann-Whitney U tests for 2 unrelated independent samples were performed for each parameter. Mann-Whitney U statistics, Wilcoxon W statistics, and p-values were obtained, with a level of significance set at P=0.05.

Results

Umbrella Diameter and Mass

A linear relationship (Figure 1) was found between umbrella diameter and wet weight in both wild and Aquarium-reared *Aurelia sp*. Wild *Aurelia sp.* caught off of Jamaica Bay (n=40) yielded a relationship of Mass (g) = 4.71 x Umbrella Diameter (cm) - 21.17, with a standard error of 3.97 for b_0 and 0.47 for b_1, and R-squared = 0.79. An ANOVA F-test resulted in an F statistic of 99.71 and a p-value $\leq$ 0.000. Captive *Aurelia sp.* yielded a relationship of Mass (g) = 4.56 x Umbrella Diameter (cm) - 17.33, with a standard error of 2.39 for b_0 and 0.35 for b_1, and R-squared = 0.72. There were no statistical differences between sample groups for umbrella diameter or wet weight.

Proximate Nutrient Composition of A. aurita

Nutritional / chemical composition as percent of dry matter (DM) is seen in Table 1. Samples contained 97-98% water.

Crude protein content was found to be significantly higher in wild *A. aurita* samples than in captive *A. aurita* samples with a p-value of .002 (Mann-Whitney U statistic = 0.00, Wilcoxon W statistic = 15.00). Fat content was found to be significantly higher in captive samples than in wild samples, with a p-value of 0.009 (Mann-Whitney U statistic = 2.00, Wilcoxon W statistic = 23.00). Percent ash was found to be greater in wild samples than in captive samples, with a p-value of 0.05 (Mann-Whitney U statistic = 0.000, Wilcoxon W statistic = 6.00). Vitamin E activity was significantly higher in captive samples than in wild values, with a p-value of 0.004 (Mann-Whitney U statistic = 17.00, Wilcoxon W statistic = 62.00). Differences in vitamin A activity were not statistically significant (p-value= 0.240; Mann-Whitney U statistic = 28.00, Wilcoxon W statistic = 64.00).

Using the Atwater method to determine energy content, [Energy Content (Kcal/g) = 4 X % carbohydrate content + 9 X % fat content + 4 X % protein content (USDA)], wild *A. aurita* samples contained 0.55 to 1.3 kcal/g DM and captive *A. aurita* samples contained 0.66 to 1.65 kcal/g DM (the higher number, in each case, determined by calculating total carbohydrates as (100 – ash – protein – fat) in case other constituents not measured might have been present). This translates to approximately 0.01 to 0.03 or 0.04 kcal/g of wet tissue in samples.

Proximate Nutrient Composition of Aquarium Provided Diet. Nutritional differences are evident in the various foods provided at NYA and are seen in Table 2.

Mineral Composition of A. aurita and NYA Provided Diet

A. aurita were analyzed for sodium (Na), magnesium (Mg), phosphorous (P), potassium (K), calcium (Ca), manganese (Mn), iron (Fe), cobalt (Co), arsenic (As), copper (Cu), zinc (Zn), molybdenum (Mo), cadmium (Cd), selenium (Se), and lead (Pb). Striking differences were found in Zn levels, with wild *A. aurita* containing 72.8 ± 2.5 mg/kg Zn, and captive *A. aurita* containing 17.9 ± 0.1 mg/kg (DM basis). Phosphorous levels were also quite different; 2870 ± 80 mg/kg in wild and 1420 ± 160 mg/kg in captive cultured *A. aurita.* Magnesium levels were 3.95 ± 0.09 mg/kg in wild and 0.54 ± 0.01 mg/kg in captive *A. aurita*. Levels of the other studied minerals were comparable between wild and captive bred groups. These data are shown in Table 3, as is the mineral composition of the aquarium prepared diet

Discussion

Composition

This study was able to determine the proximate composition of wild, Jamaica Bay, NY, *A. aurita,* as well as of captive, NY Aquarium-cultured *A. aurita* originating from a Brooklyn, NY strain. The investigation showed that the proximate compositions differed, with the wild *A. aurita* possessing approximately half the fat and twice the protein of captive reared counterparts.

It is useful to compare the data in this study to the data obtained from prior studies (Table 1). Ash has been reported as 79% DM by Larson[16] and as 20-54% DM in other studies[4], with larger medusae containing less ash[17]. Protein has been reported as 1.9 percent overall DM[5], as 2-8 percent DM in umbrellar tissue[17], and as 4-23% DM in gonadal tissue[17]. Carbohydrate has been reported as 0.3-2% DM in Lucas[17] and as 2.8% DM in Schneider[5]. Lipid has been reported as 0.9-2.9% of DM in whole animals[5], and as 2.6-6% of DM in the gonads[17]. Although they did not appear physically obese, captive-reared jellyfish in this study may have been chemically obese by comparison with wild medusae and literature data, but there are few physiologic measures to make a definitive determination.

In addition to the quantitative differences, a number of physical attributes did appear to differ between the wild and captive *A. aurita* examined in this study. Upon handling by the investigators, live Aquarium-reared jellyfish produced more mucus and stung more often than did their live, wild counterparts. After placement in a subzero freezer for 24 hours, tissues from Aquarium-reared *A. aurita* crumbled when handled, while tissues from wild caught *A. aurita* did not. Finally, Aquarium-reared *A. aurita* appeared to exhibit gonads when their umbrella diameters reached approximately 3 cm, while the wild Jamaica Bay *A. aurita* did not exhibit gonads until they were approximately 6 cm in umbrella diameter. It is possible the captive animals reached sexual maturity at an earlier age than wild jellyfish.

From the data presented here, there appear to be significant differences in the proximate compositions of wild and Aquarium-cultured *A. aurita*. However, this study does not prove that the Aquarium-reared *A. aurita* are unhealthy, nor can it alone be used to assume that diet changes should be made in order to replicate the proximate composition of the wild *A. aurita*. In order to make these assertions, chemical composition and diet must be correlated with observed reproductive and overall success [rather than size or sexual maturity which has been studied by Lucas[17]; controlled feeding trials on diets of different composition should be conducted.

Such nutritional studies on *A. aurita* medusae must be applied to aquaria husbandry practices. Aquarium husbandrists are often feeding what they believe to be the best diet based upon trial-and-error practices rather than on scientific data. Qualities that may make the animal look better for public presentation may not necessarily be optimal for the animals. When taken together, these factors are suggestive of imperfect constitution and possible nutritional imbalance. All other husbandry factors, such as water quality, density of medusae, kreisel size, and various other factors must, of course, be recognized as well.

Many factors directly observed in this investigation may also suggest nutritional issues in the captive jellyfish. During this investigation, the crumbling of *A. aurita* tissue was readily apparent in captive samples and not present in wild caught samples. This is perhaps indicative of structural integrity flaws within the captive *A. aurita*. As the proteinaceous mesoglea acts as a major factor providing structural support, the apparent low protein levels in the captive samples may underlie this problem. While reported values of crude protein content do go as low as 2.1% of DM in *Aurelia* spp[17]. (Table 4), they may not be applicable to this size or strain of medusae.

The gonadal development by small sized captive medusae (3 cm) was similarly visually apparent in captive *A. aurita* but not in wild *A. aurita*. This may also be the result of either over- or undernutrition in the captive stock. Wild specimens did not appear to develop gonads until they had reached a much larger size, with the smallest gonad-exhibiting wild caught medusa 6 cm in umbrella diameter, and most gonad-exhibiting medusae at least 8 cm in umbrella diameter.

It has been shown that medusae in food-limited areas produce gonads at an earlier size than do medusae at larger sizes. Prior studies have shown food-limited *A. aurita* to produce gonads at 4.5 cm[19] and 5 cm[13] with well-fed medusae producing gonads at over 9 cm in umbrella diameter[13]. Thus, Aquarium-reared *A. aurita* may be “food-limited” or may be receiving a diet deficient or imbalanced in one or more critical nutrients.

Spangenberg[25] has reported that subsequent to gonadal development and sexual maturation, *A. aurita* regressed and disintegrated. This may also be the cause of the hypothesized structural integrity problem.

Most obviously, however, it suggests that early gonadal development, such as in the Aquarium *A. aurita*, is "unhealthy" and results in high mortality. Additionally, early gonadal development in starved *A. aurita* has been shown to result in fewer offspring[19].

Taking into account the small size of the Aquarium-reared *A. aurita*, it is possible that the presence of gonadal tissues led to, or is a result of the comparatively high fat content. The chemical composition of *A. aurita* is significantly related to the different tissue types present in the medusa, including gonadal tissues; Lucas[17] reports gonadal tissue as far fattier (with a fat content of 2.6-6.0% of DM) than other tissue (with a fat content less than 3.4% of DM).

It is thus apparent that the captive, New York Aquarium-reared *A. aurita* (Brooklyn strain) had proximate nutritional compositions that differed from those of wild, Jamaica Bay (Brooklyn) *A. aurita*. The captive *A. aurita* may thus be overfed some nutrients and underfed others. In order to determine if this is the case, future research involving growth trials and further compositional analysis much be completed, as will be discussed.

Future Research

One avenue of future research is to provide differing diets in *ex situ* growth trials, after which proximate composition can be determined. As this study examined the proximate composition of the diet fed to Aquarium-cultured *A. aurita*, fat and protein sources can be identified. Super Selco® enriched *Artemia* had a higher fat content than did any of the other foods studied. Cyclop-eeze® had a higher protein content than did any of the other food studied. Note that the water content value of enriched *Artemia* was not obtained due to laboratory error (but rather estimated from other studies conducted at the same institution; i.e. Greco et al., 1998). Cyclop-eeze® was not found to have any vitamin A activity; however, preparation for HPLC may have been incorrect and thus led to an inaccurate value. The capelin mix contained a high standard error for all values, especially percent ash. This may be due to poor homogenization of the sample, although the sample did visibly appear to be homogenized.

Using the nutritional composition data obtained in this investigation, various trials can be performed. One recommended trial is to use nonenriched *Artemia* nauplii rather than Super Selco®-enriched nauplii as the mainstay of the captive diet. Prior studies have shown that *A. aurita* are attracted to *Artemia*[3] and growth trials in ephryae *A. aurita* (*A. aurita* in the stage prior to medusa) have found *Artemia* to be an efficacious diet that led to higher growth rates than did diets of particulate clam meat[6]. Furthermore, the majority of studies involving *ex situ A. aurita* used unenriched *Artemia* as the primary diet.

While studies have shown that various types of fish grow more successfully when fed Super Selco® enriched rather than unenriched nauplii, e.g. Woods[29], this has not been studied in *A. aurita*. In fact, there are no published data regarding feeding Super Selco® enrichment to scyphozoans. As *A. aurita* are not fish, but rather invertebrates, it is possible that the fatty acids provided by Super Selco™ are unnecessary in *A. aurita*. Previous investigations show that unenriched *Artemia* nauplii contain 13% fat[11] rather than the 24% found in the enriched nauplii in this study. Using this diet would thus likely reduce the overall fat content of the *A. aurita*.

Anecdotal reports by other aquariums have stated that *A. aurita* fed nonenriched *Artemia* nauplii diets do not "look good." However, as discussed earlier, external appearance does not necessarily equate with optimal health. If test trials show that it is in fact the case that the fatty acids provided by Super Selco® are necessary for the *A. aurita*, further trials could alternate feeding enriched vs. nonenriched nauplii to determine

the optimized frequency with which enriched nauplii should be fed.

Additional growth trials might alter the Aquarium diet in other ways, such as increasing the amount of Cyclop-eeze® and decreasing the amount of *Artemia*. This would presumably increase the protein content and possibly result in better tissue integrity. With any diet, however, it is important to note that husbandry practices may have to change as well. Providing a more proteinaceous diet might require lowering water temperatures, as protein metabolism produces more heat than does fat metabolism. Using other foods such as the capelin mix might require increased tank cleaning and water changes as a result of oil in the diet.

Furthermore, as the captive cultured *A. aurita* originated from the same strain as did the wild, Jamaica Bay *A. aurita*, it may be useful to obtain more data as to the proximate composition of the wild *A. aurita*. For the reasons discussed earlier, including seasonal and water chemistry changes, the proximate composition of *A. aurita* should be determined in samples from water closer to the Aquarium intake pipeline, and over various seasons. This will provide a stronger basis of comparison for captive *A. aurita* samples.

Additional Avenues of Investigation

In order to apply this investigation to future research, it is important to note a number of factors that may have affected the results. These factors include: sample size, water chemistry, and other possible analytical inaccuracies.

As *A. aurita* samples contained 97-98% water, it was impossible to use individual jellyfish (mean = 15 g) for multiple laboratory tests which required 0.5 g each. Additionally, due to time and budget constraints of New York Aquarium / Wildlife Conservation Society staff members, this study was only able to examine 40 wild *A. aurita* and 43 captive *A. aurita*. Thus, we were forced to homogenize large numbers of jellyfish and create only a small number of freeze-dried pools, which we sampled for laboratory analysis. Therefore, sample size was fairly low for chemical composition tests.

Results may also have been affected by the fact that water chemistries from Jamaica Bay and the Aquarium kreisel were not analyzed. As *A. aurita* are believed to be osmoconformers[4], water chemistry may have had an effect on chemical composition. Shick[22] reports dissolved amino acid uptake as relative to temperature, environmental conditions, and feeding. It is thus difficult if not impossible to separate "nutrition" from water chemistry. Therefore, one cannot assume that differences in composition are exclusively due to diet rather than environment. This is especially the case when one considers that laboratory analysis did not differentiate whether or not the proteins, fats, and other compounds present in *A. aurita* were of dietary origin and simply a factor of gut contents rather than utilization and incorporation by the organism. Thus begs the question of "What's in the water?"

Concerning water chemistry, it is useful to consider that sampling *A. aurita* during a different season may have resulted in differing chemical compositions. Fatty acid composition has been shown to differ in samples of *A. aurita* collected in April/June compared with August/September. This is likely a result of temperature change in the marine ecosystem leading to increased diatom prey in April/June and increased detritus in August/September[9]. Similarly, seasonal variation in diet has been observed through gut content analysis[14]. It is thus to be expected that overall nutritional composition will change between seasons as well (this will also affect intake water at the NYA).

In examining these data, it is also important to take into account the laboratory processes and calculations. In order to obtain crude protein values for this study, nitrogen content was multiplied by 6.25, as discussed in Robbins[21]. However, this constant has not been precisely determined for jellyfish.

Finally, in examining the wild-caught Jamaica Bay *A. aurita*, it is important to note that there are no data to prove that these free-ranging jellyfish are healthy. Assuming that because they live in the wild, they are healthy, is naïve at best. As *A. aurita* were taken from low salinity surface waters, and as a number of water sources flow into Jamaica Bay with possibly contaminated water, sampled *A. aurita* may or may not have had ideal chemical compositions.

These critiques, however, can be somewhat rectified by comparing data from this study to data from other investigations (Table 1). These data do show that captive reared *A. aurita* samples in this study contain a higher fat content than has been reported in any other population.

Conclusion

Proximate compositions between Aquarium-reared *A. aurita* and wild, Jamaica Bay *A. aurita* differ in various ways including fat, protein and mineral content. While this is likely the effect of diet, further research is needed to determine other factors as well as whether or not these differences are significant. Understanding the nutritional composition of *A. aurita* can lead to valuable insights into the marine ecosystem as well as for the aquaculture community.

The direct implications of this study are of considerable use to the aquarium community. The study provides background data that can be used to formulate more nutritious diets for Aquarium-reared *A. aurita*. Such diets can lead to better health, longevity, and appearance in captive specimens. Additionally, a more cost-effective diet can be formulated. As *Artemia* cysts and enrichment preparations such as Super Selco® are expensive, other diets and sources of nutrition may be quite useful.

This study also has broad indirect applications. *A. aurita* are a major food source for loggerhead sea turtles and other animals, and understanding the nutritional composition of *A. aurita* can likely lead to a better understanding of their predators' needs. This is especially important as the proximate composition of *A. aurita* significantly differs from the composition of more traditionally studied organisms such as fish. Furthermore, understanding the feeding patterns of *A. aurita* may result in a better understanding of where they will become invasive [Fukuda 2001], while their composition may be an indicator or water quality.

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Figure 1. Comparison of umbrella diameter to mass.

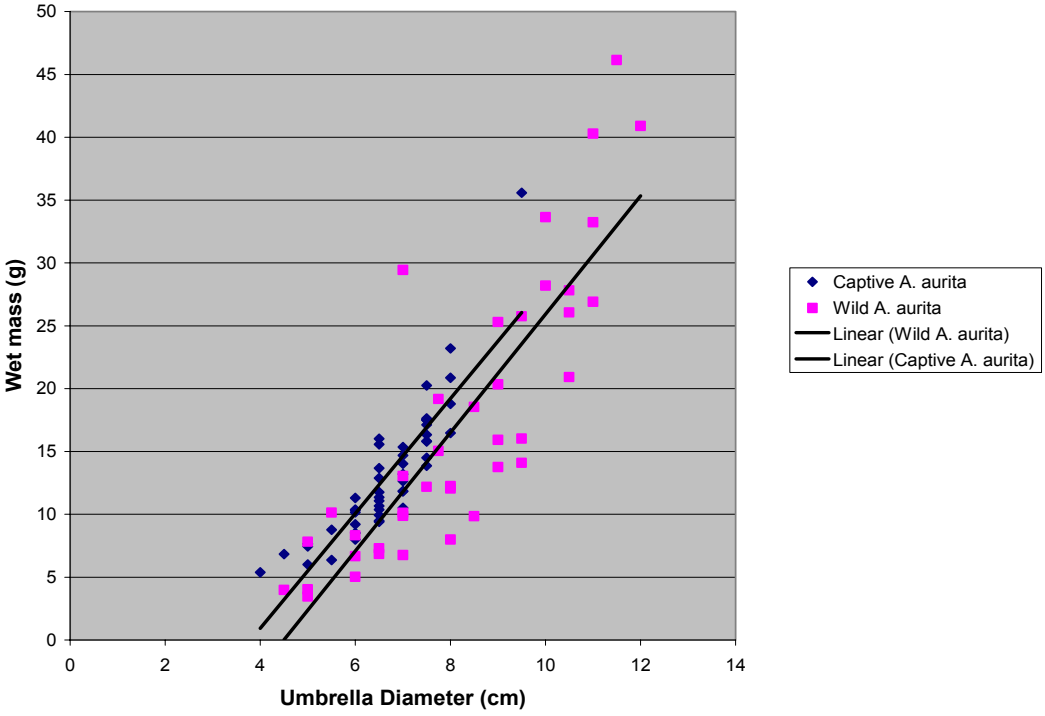

Table 1. Nutritional composition of *Aurelia sp.* Values are mean ± standard error; all values on a dry matter basis, except water content.

Nutrient	Wild *A. aurita*, This study	Captive *A. aurita*, This study	Wild, whole *A. aurita*[1]
Water (%)	97-98	97-98	ND
Crude Protein (%)	9.20±0.4 n=4	4.95±0.2 n=6	2.1-28.6
Crude Fat (%)	2.05±0.37 n=6	5.16±1.00 n=4	0.2-3.4
Carbohydrate (%)	None Detected n=9	None Detected n=6	0.4-2.9
Ash (%)	69.88± 0.70 n=3	64.87±0.12 n=3	20-79
Vitamin A Activity (IU/g DM)	0.045±0.019 n=9	0.070±0.40 n=8	ND
Vitamin E Activity (IU/kg DM)	9.8±4.8 n=8	57.4±16.5 n=8	ND

[1]Reported values are from Arai [1997], and Schneider [1988] as reported in Bailey et al [1995].
ND = not determined

Table 2. Nutritional composition of NY Aquarium diet ingredients fed to captive jellyfish. Values include mean ± standard error.

Foodstuff / **Nutrient**	**Enriched *Artemia***	**Cyclop-eeze®**	**Capelin mix**
Water Content (%)	ND	83.48	80.77
Crude Protein (% of DM)	43.54 ± 1.35 n=2	63.36 ± 2.04 n=2	42.60 ± 1.98 n=2
Crude Fat (% of DM)	23.95 ± 0.37 n=2	23.06 ± 1.60 n=2	20.00 ± 1.34 n=2
Ash (% of DM)	11.80 ± 0.52 n=2	15.36 ± 0.38 n=2	19.42±13.72* n=2
Vitamin A Activity (IU/g DM)	3.5 ± 0.54 n=3	None Detected	37.10 ± 7.09 n=3
Vitamin E Activity (IU/kg DM)	68.64 ± 3.34 n=3	101.03 ± 2.21 n=3	160.94 ± 28.72 n=3

ND = not determined
* These values may include analytical error.

Table 3. Mineral content of wild-caught and captive-reared *Aurelia sp.*, and ingredients in captive diets. Values are mean ± standard error; all values on a dry matter basis, in mg/kg (ppm).

Mineral	Wild *Aurelia* sp. (n=3)	Captive *Aurelia* sp. (n=2)	Enriched Artemia	Cyclop-eeze	Feed Mix
Na	244000 ± 4400	265000 ± 13000	15700	35200	16800
Mg	27900 ± 210	28300 ± 1200	2580	9220	1740
P	2870 ± 80	1420 ± 160	11000	6630	10800
K	11700 ± 500	13050 ± 1050	13400	8500	14500
Ca	8380 ± 160	9030 ± 290	785	3890	9330
Mn	3.95 ± 0.09	0.54 ± 0.01	9.69	15.1	14.3
Fe	119 ± 2	55.3 ± 3.1	86.7	417	309
Co	0.07 ± 0.01	<0.05	<0.05	0.73	<0.05
As	1.77 ± 0.01	1.05 ± 0.04	25.1	6.42	4.66
Cu	6.08 ± 0.52	4.25 ± 0.57	5.41	11.2	11.5
Zn	72.8 ± 2.5	17.9 ± 0.1	111	83.3	86.2
Mo	0.453 ± 0.010	0.370 ± 0.034	0.223	0.417	2.61
Cd	0.14 ± 0.1	0.07 ± 0.03	<0.03	0.16	0.39
Se	0.37 ± 0.09	0.30 ± 0.01	1.56	2.28	1.99
Pb	<0.5	<0.5	80.4	<0.5	<0.5

PARASITES OF THE SYNGNATHIFORM FISHES AND THE IMPLICATIONS FOR HUSBANDRY AND QUARANTINE

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Introduction

The following is a concise review of the metazoan parasites of syngnathiform fishes and their allies common to public aquaria, exclusive of the Gasterosteidae, whose parasitofauna has been thoroughly reviewed in Hoffman (1999). This review draws upon the primary literature, the aquarium literature, and the parasite collections of the world's preeminent museums (United States National Parasite Collection, Harold W. Manter Laboratory of Parasitology, and the Natural History Museum, London). At first glance the literature would seem bereft of references to seahorse and pipefish parasites; but the commonplace anecdotal descriptions of ectoparasites by aquarists and divers as well as the routine findings of encysted endoparsites in histopathology reports would suggest that the extent of parasitism in this group is scarcely known with certainty. As such, the following should not be viewed as an authoritative list of parasites for the group, but rather a summation of questions left unanswered: a template on which to start recording and reporting new incidences of parasitism in the syngnathiform fishes.

A Checklist of the Metazoan Parasites of Syngnathid Fishes and Allies

The following is a taxonomic listing of syngnathiform fishes with published records of metazoan parasites. The fishes are presented in phylogenetic order to subfamily following Nelson (1994), with Latin binomials being presented alphabetically thereafter. Scientific names of fishes follow Fishbase (Froese and Pauly, 2008), while binomials of parasites are consistent with their cited reference. The parasites are grouped by class and presented in phylogenetic order following Ruppert and Barnes (1994); individual parasite species are presented in alphabetical order thereafter. The microsporidian parasites are grouped here with the class Myxozoa (Cnidaria) in keeping with the work of Siddall et. al. (1995), although their exact classification is still a topic of some debate. It is also worth noting that the host families Hypoptychidae, Aulorhynchidae, Fistulariidae, and Indostomidae were excluded here as they are less commonly kept in aquaria (though a significant number of parasites are known from wild specimens of the cornetfishes).

Solenostomidae
- *Solenostomus cyanopterus**
- *Solenostomus paradoxus**

Syngnathidae
- Hippocampinae
  - *Hippocampus abdominalis*
    - Trematoda
      - Trematode sp. unknown (Woods, 2007)
  - *Hippocampus barbouri*
    - Myxozoa
      - "Microsporidian" sp. unknown
        - (Berzins and Greenwell, 2005)
  - *Hippocampus bargibanti**

*Hippocampus breviceps**
*Hippocampus capensis**
Hippocampus erectus
Myxozoa (Microsporidia)
*Glugea heraldi***(Blasiola, 1979)
Nematoda
Nematode sp. unknown (Vincent and Clifton-Hadley, 1989)
Crustacea
Lernaeopodidae sp. unknown (Berzins and Greenwell, 2005)
Arachnida
Acari sp. unknown (www1, 2006)
*Hippocampus fuscus**
Hippocampus guttulatus
Trematoda
Cardiocephalus longicollis (Dimitrov, 1989)
Acanthocephala
Telosentis exiguus (Belofastova and Korniychuk, 2000)
*Hippocampus ingens**
*Hippocampus kelloggi**
*Hippocampus kuda**
*Hippocampus procerus**
*Hippocampus reidi**
Hippocampus ramulosus
Nematoda
Ascaris hippocampi (Bruce et. al., 1994)
*Hippocampus subelongatus**
Hippocampus trimaculatus
Trematoda
Dollfustrema hippocampi (NHML)
Opegaster hippocampi (NHML)
Opegaster tamori (NHML)
Telorhynchus hippocampi (NHML)
*Hippocampus whitei**
*Hippocampus zosterae**
Myxozoa (Microsporidia)
*Glugea cf. heraldi*** (Potvin, B. Personal Communication)
Hippocampus sp.
Acanthocephala
Corynosoma australe (Braicovich et. al., 2005)
Syngnathinae
*Corythoichthys intestinalis**
*Cosmocampus elucens**
*Doryramphus dactyliophorus**
*Doryramphus excisus excisus**
*Doryramphus janssi**
*Doryramphus multiannulatus**

*Doryramphus pessuliferus**
*Haliichthys taeniophorus**
*Hippichthys heptagonus**
*Hippichthys spicifer**
*Microphis brachyurus aculeatus**
*Microphis brachyurus brachyurus**
*Microphis brachyurus lineatus**
*Microphis fluviatilus**
Nerophis ophiodon
- Nematoda
  - *Hysterothylacium aduncum* (Zander, 2005)

Phycodurus eques
- Crustacea
  - Isopod sp. unknown*** (Browne and Smith, 2007)

Phyllopteryx taeniolatus
- Myxozoa
  - *Sinuolinea phyllopteryxa* (Garner et. al., 2008)

Stigmatophora nigra
- Monogenea
  - Gyrodactylidae sp. unknown (Ernst et. al., 2001)

Syngnathoides biaculeatus
- Monogenea
  - "Flukes" sp. unknown (Burhans, 2004)

Syngnathus acus
- Myxozoa
  - *Kudoa cf. quadratum* (Longshaw et. al., 2004)
  - *Myxidium cf. incurvatum* (Longshaw et. al., 2004)
- Trematoda
  - *Cryptocotyle lingua* (Longshaw et. al., 2004)
  - Trematode sp. unknown (Longshaw et. al., 2004)
- Cestoda
  - Cestode sp. unknown (Longshaw et. al., 2004)

Syngnathus fuscus
- Monogenea
  - *Gyrodactylus pisculentus* (USNPC)
  - *Gyrodactylus sp.* unknown (www1, 2006)
- Trematoda
  - *Bianium plicitum* (Bray et. al., 1996)
  - *Opecoeloides vitellosus* (www1, 2006)

Syngnathus griseolineatus
- Mongenea
  - *Gyrodactylus sp.* (Rohde et. al., 1995)
  - *Microcotyle sebastis* (Rohde et. al., 1995)
  - "Flukes" sp. unknown (Burhans, 2004)
  - *Gyrodactylus sp.* (Appleton and Cone, 1992)
- Trematoda

Lecithaster gibbosus (NMHL)
Opechona occidentalis (Bray et. al., 1990)
Parahemiurus merus (Bray, 1990)
Podocotyle enophrysi (NHML)
Podocotyle sinusacca (NHML)
Tubulovesicula lindbergi (NHML)

Nematoda

Syngnathinema californiense (Moravec et. al., 2001)

Syngnathus louisianae

Monogenea

Gyrodactylus cf. shorti (Author- Unpublished Observation)

Syngnathus narinosa

Crustacea

Isopod sp. unknown*** (Browne and Smith, 2007)

Syngnathus nigrolineatus

Trematoda

Bucephalus sp. Metacercariae (NHML)
Diplostomum sp. Metacercariae (NHML)

Cestoda

Proteocephalus sp. juv. (NHML)

*Syngnathus pelagicus**

Syngnathus rostellatus

Monogenea

Gyrodactylus syngnathi (Appleby, 1996)

Nematoda

Cosmocephalus obvelatus (Palm et. al., 1999)
Hysterothylacium sp. (Palm et. al., 1999)
Paracuaria tridentate (Palm et. al., 1999)
Pseudoterranova decipiens (Palm et. al., 1999)

Syngnathus scovelli

Monogenea

Gyrodactylus shorti (Holliman, 1963)

Syngnathus typhle

Trematoda

Acanthostomum balthicum (Zander, 2001; Zander 2005)
Acanthostomum imbutiformis (Domnich & Sarabev, 2000)
Acanthostomum sp. (Palm et. al., 1999)
Cryptocotyle concava [sic] (Palm et. al., 1999)
Cryptocotyle concavum (Zander ,2001, Zander, 2005)
Cryptocotyle lingua (Domnich and Sarabev, 2000)
Diplostomum spathaceum (Palm et. al., 1999)
Hemiurus luehei (Palm et. al., 1999)
Podocotyle atomon (Zander et. al., 1999)
Pygidiopsis genata (Domnich and Sarabev, 2000)
Thersitina gasterostei (Zander, 2001)
Timoniella imbutiforme (Palm et. al., 1999)

Cestoda
Bothriocephalus scorpii (Zander et. al., 1999)
Nematoda
Anguillicola crassus (Palm et. al., 1999)

Syngnathus typhlops
Trematoda
Acanthostomum imbutiformis
(Argumedo and Rodriguez, 1984)
Nematoda
Anguillicola crassus (Reimer et. al., 1994)

Syngnathus sp.
Trematoda
Cryptocotyle concava [sic] (Palm et. al., 1999)
Podocotyle atomon (USNPC)
Acanthocephala
Acanthocephaloides incrassatus
(Domnich and Sarabev 2000)
Corynosoma strumosum (Ibragimov, 1988)

Aulostomidae
Aulostomus chinensis
Trematoda
Bulbocirrus aulostomi (Bray and Cribb, 2003)
Stephanostomum nunu (Bray and Cribb, 2003)
Crustacea
Caligus sp. (Gonzalezi et. al., 1997)
Aulostomus maculatus
Trematoda
Stephanostomum aulostomi (Bray and Cribb, 2003)

Macroramphosidae
*Macroramphosus scolopax**

Centriscidae
*Aeoliscus strigatus**
*Aeoliscus punctulatus**

**No published record of parasite fauna in primary literature or major museum collections but species has been kept in public aquaria.*

***Tentatively grouped here with the Myxozoa solely based on pathology and morphology as the taxonomy of the Myxozoa and Microsporidia has yet to be authoritatively reconciled – by no means is this account intended to be systematically authoritative.*

****These are believed by the author of the cited reference to be the same species of parasitic isopod based on gross appearance and zoogeography*

Brief Summary by Parasite Classification:

Cnidaria: Myxozoa

Myxozoan parasites have been definitively identified in four syngnathid species and there is a tentative report of "microsporidians" in other species. The Myxozoa, in general, are known to cause a number of diseases such as whirling disease and proliferative kidney disease (PKD) in salmonid fishes as well as other health conditions. *Glugea spp.* are currently classified as Microsporidian Protozoa but are listed here alongside the Myxozoa provisionally simply based on the similarities in morphology and pathology pending an authoritative taxonomic separation of the Myxozoa from the Protozoa.

Platyhelminthes: Turbellaria

No turbellarians have yet been documented in the literature despite being relatively commonplace in other groups of tropical marine fishes.

Platyhelminthes: Monogenea

Monogeneans (often incorrectly referred to as external "trematodes") are ectoparasitic flatworms that most aquarists are all too familiar with, given their propensity to rapidly multiply causing disease and mortalities among captive fishes. It has been stated that there are no published reports of monogenean infections in syngnathid fishes (Berzins and Greenwell, 2005), though at least 5 definitive reports exist in the primary literature of such infections. Another 6 unpublished or unconfirmed reports are listed here, for a total of 11 records of parasitism. Given the number of anecdotal reports of monogenean outbreaks in numerous aquaria worldwide (Berzins and Greenwell, 2005; personal observations; Aquaticinfo List-Server); it is very likely the list of syngnathid species susceptible to monogenean infestation is far more inclusive than the checklist presented here.

Platyhelminthes: Trematoda

The trematodes are endoparasites with complex life cycles, and are the parasite taxon best represented in the current review; with 37 records of parasitism (35 identified at least to genus, 2 unknown spp.). Of these there are as many as 32 individual parasite species represented; which is to be expected given the relatively high degree of host specificity in the trematodes. Many of the published records in the syngnathidae are of encysted trematode metacercariae; this coupled with the complexity of the trematode life cycle would seem to indicate that these parasites are of little threat to individual specimens, and even lesser threat to captive populations. Berzins and Greenwell (2005) noted this group to be among the most common endoparasites of syngnathids, which is wholly supported by the sheer number of incidences of parasitism and relative diversity listed in this review. It is also noteworthy that there have been no hematoparasites of syngnathids reported yet to date, despite several investigations of syngnathid blood (Saunders, 1960; Hill and Hendrickson, 1991)

Platyhelminthes: Cestoda

Tapeworms are extremely common in marine fishes, but are the least represented of the platyhelminth parasites in this review, with only 3 infections documented. It is also quite noteworthy that of these infections one was identified from pleurocercoid larvae (NHML) and another was unidentifiable being that only proglottids were discovered (Longshaw et. al., 2004). Berzins and Greenwell (2005) listed cestodes among the most frequently encountered endoparasites encountered in public aquaria, and given the sparse reports of such parasites it would thus seem that the cestode fauna has been grossly under-reported in the primary literature. In general the cestodes have relatively complex life cycles with varying amounts of host specificity, and as such are of low risk to groups of captive animals as a whole, although heavily parasitized individuals may suffer obstruction of the gastrointestinal tract or become emaciated. Given the necessity of constant

foraging and relative inability of synganthids to store appreciable amounts of fat reserves, adult cestodes obviously have the potential to be problematic to individual captive specimens. Encysted larval forms (cysticercus, oncosphere, procercoid, pleurocercoid), however, are of much less concern than adults.

Acanthocephala

Thorny-headed worms are gastrointestinal parasites which are common in most groups of freshwater and marine fishes, but are represented by only four records amongst the Syngnathidae. This group is similar to the Trematoda and Cestoda in that high infection intensities may be problematic for individual hosts in captivity, though the complexity of the life cycle prevents this group of parasites from being major threats to captive populations of fishes as a whole.

Nematoda

The roundworms are relatively well-represented in the literature as parasites of the syngnathiformes, with 9 records of parasitism from at least 8 species (plus one unidentified species). The impact of nematodes on captive populations of syngnathid fishes is not known with certainty, though they have been considered parasites of some concern in other groups of fishes (Benz and Bullard, 2004). The impact on captive populations could be very little as most species have relatively complex life cycles.

Annelida: Hirudinea

There are no reports of leeches parasitizing syngnathiform fishes in the primary literature. There are scattered anecdotal reports online of hirudineans parasitizing seahorses from aquarium hobbyists, though there is the possibility these were mistaken for monogeneans. However, given the simple life cycles and lack of host specificity exhibited by many hirudinean parasites, especially those of the family Piscicolidae, the possibility of leech infestation in mixed species tanks should not be discounted.

Arthropoda: Crustacea

Anecdotal reports of crustacean parasites on syngnathid fishes exist from both public aquaria (Berzins and Greenwell, 2005) and from sightings by divers and aquarium hobbyists. While there are a number of these observations (and even some photos posted on the internet) though these are backed up by only a scant few published references. In describing a new pipefish species, *Stigmatopora narinosa*, Browne and Smith (2007) reported and photographed an isopod on the species. It is further noted that the parasite is believed to be the same species of isopod found in the same locality on *Phycodurus eques* (Browne and Smith, 2007). Gonzalezi et. al. (1997) related accounts of copepods of the genus *Caligus* in the trumpetfish, *Aulostomus maculatus.* Berzins and Greenwell (2005) summarized a number of the informal reports of metazoan parasites from public aquaria, noting that Argulus sp. (Branchiura), and Lernaeopodid copepods have been encountered in seahorses. Given the lack of host specificity in many crustacean parasites and the number of anecdotal reports of parasitism, it is likely that our knowledge of the extent of crustacean parasitism in this group of fishes is rudimentary, at best.

Arthropoda: Arachnida

There are no published reports of any arachnid parasites of syngnathid fishes, though there was a report and photomicrograph of a mite (Acari, sp. unknown) from *H. erectus* that was posted on the now defunct Fishdisease.net database (www1, 2006).

Implications for Husbandry and Quarantine

The implications of understanding the parasite fauna of any group of fishes upon husbandry are complex and subjective. While only a few of these parasite groups trend towards being problematic (i.e. the Myxozoa, Monogenea, Crustacea), the extent to which some other groups of parasite fauna may impact husbandry can scarcely be estimated given the current knowledge. It has been acknowledged in numerous works (most specifically to syngnathids Berzins and Greenwell, 2005) that when encountered the encysted forms of many of the endoparasitic taxa (i.e. Trematoda, Cestoda) are relatively quiescent, and this holds true in many other taxa of host fishes as well (i.e. Benz and Bullard, 2004). Many of these parasites are of little or no risk to captive populations because their complex life cycles preclude transmission to their conspecifics (i.e. Trematoda, Cestoda, Acanthocephala). The fact that horizontal transmission is near-impossible also calls into question the practice of periodically (i.e. annually, quarterly) de-worming fishes, as it is rather unlikely that they could face re-infection as is common in terrestrial animals. It can thus be inferred that only certain taxa are of great concern to captive groups, and that on the whole the metazoan parasite complement of syngnathid fishes are of less concern than many of the highly pathogenic protozoan parasites. There are, however, some potential impacts that these parasites may have on husbandry in terms of breeding programs. Rosenqvist and Johansson (1995) found that males of *Syngnathus typhle* discriminate against females with higher intensities of encysted trematode metacercariae (*Cryptocotyle sp.*), and that there was a negative correlation between parasite burden in females and fecundity. Mazzi (2004) found that male pipefish of the same species had lower production of offspring overall, but that the offspring were of the same size, and thus of equivalent approximate fitness as those carried by non-infected males. Given how little is known of parasite distribution and infection intensities across the syngnathidae, much less of their host-altered behavior or fecundity, there may be greater impacts on *ex situ* breeding populations than has been previously considered, at least among broodstock obtained from wild populations.

The implications of understanding the parasite fauna of the syngnathid fishes go beyond the disciplines of parasitology and aquarium husbandry, having a broader impact on understanding the ecology of these fishes, their aquaculture, and on conservation science. Parasites are useful in a variety of ecological studies as biological tags, especially in diminutive species such as seahorses and pipefish. It has been noted that the potential exists for using parasite tags for stock identification and in tracing the commercial trade of seahorses and pipefish (Morgan and Bull, 2005), though such efforts would only be possible with a significantly greater understanding of their parasite fauna. A good deal of effort in recent years has been devoted to refining the techniques for the culture of seahorses in captivity, both for sustaining aquarium populations and in commercial endeavors. A more thorough knowledge of the parasite fauna would be of obvious benefit to these activities in terms of developing quarantine protocols and potentially even improving production. Another practical benefit to having a more robust understanding of this subject is not just to maximize aquaculture efforts, but also to minimize the risks of disease transmission inherent with any future conceivable stock enhancement programs as outlined by Vincent and Koldewey (2006). Such programs could easily prove to be ecologically disastrous without proper planning and implementation, as has been seen in other species, though not yet in syngnathids (Vincent and Koldewey, 2006).

In summary there is still much to learn about the extent of parasitism in this group of fishes; and that such parasitism could have untold consequences upon husbandry and breeding. This checklist will likely not be particularly useful to the aquarist, veterinarian, pathologist, aquaculturist, or other fish health worker in identifying specific parasite fauna, but hopefully will be found useful as a companion to the literature from which to pursue identifications or construct quarantine protocols. It is also hoped this checklist will viewed as

a concise overview of the gaps in our knowledge, and encourage greater recording and reporting of parasites from this captivating group of fishes.

Acknowledgements

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RAW 2008 ABSTRACTS
Regional Aquatics Workshop, June 16 - 19
Atlantis Marine World, Riverhead, NY, USA

Abstracts compiled by Joe Yaiullo (host); edited and matched to actual presentation schedule by Pete Mohan (D&C Editor)

[Abstracts were not submitted to Drum and Croaker for all of the papers presented. However titles, presenters, and affiliations are provided for missing abstracts.]

Monday, June 16
Pre-RAW AZA Conservation Group Working Meetings

Freshwater Fishes TAG
Marine Fishes TAG (Exec. Mtg. June 15)
Aquatic Invertebrate TAG
Coral Reef CAP
Aquatic Interest Group (AQIG)

Tuesday, June 17
Opening Session/General Interest/Shark Topics

Ozone: Preventative Maintenance and Recent Modifications

Dave Johnson, Fin-Tek Corp
For Info Contact Dave Johnson dave@fin-tek.com

Rearing the Golden Damselfish, *Amblyglyphidodon aureus*, A Promising Candidate for Aquaculture

Todd Gardner
Atlantis Marine World

Damselfishes (Pomacentridae) present a quandary for people involved in marine ornamental aquaculture. They are hardy, aggressive feeders that come in an impressive variety of brilliant colors and they are extremely popular in the marine aquarium hobby. However, despite the popularity of the entire family, only two genera of 28, *Amphiprion* and *Premnas*, have been cultured commercially. Attempts to rear species within other genera, including *Pomacentrus*, *Abudefduf*, *Chrysiptera* and *Dascyllus*, have met with little or no success to date. The reason for this is likely that their small size at hatching prevents them from accepting rotifers as a first food. Although damselfishes account for almost half of the 20-24 million individual marine ornamental fishes traded annually (Wabnitz et al. 2003), their relatively low price fails to provide an economic incentive for aquaculturists and researchers to work toward overcoming the bottlenecks preventing their commercial production.

In the investigation described herein, eggs from a pair of *Amblyglyphidodon aureus* were collected from the living coral reef exhibit at Atlantis Marine World, a public aquarium in Riverhead, NY. Three separate spawns were collected, eggs were hatched, and larvae were reared with a success rate approaching 100%, using rotifers as a first food. These preliminary successes in rearing *A. aureus* suggest that members of this genus may be good candidates for commercial aquaculture.

Fresh Water Mussels: North America's Silent Crisis

Mike Brittsan, [1] Doug Warmolts[1] and Tom Watters [2]
[1]Columbus Zoo and Aquarium
[2]The Ohio State University

The past decade has brought limited funding to many organizations, and partnerships between groups can provide methods for accomplishing needed aquatic research. Over the past decade, the Columbus Zoo & Aquarium has cooperatively initiated multiple state endangered species recovery programs with The Ohio State University, the Ohio Department of Natural Resources, Ohio Division of Wildlife, U.S. Fish and Wildlife and other agencies to create a fresh water mussel conservation facility. The above program called for creating captive breeding protocols towards reintroduction and population augmentation efforts in the state of Ohio. Goals of the facility are to restore and recover this imperiled group of organisms, as well as to serve as an immediate-need refugium. With significant mussel and fish populations in portions of the Ohio River basin, the potential to aid in recovery efforts is high. The Columbus Zoo and Aquarium Freshwater Mussel Conservation Facility is capable of holding adults in semi-natural conditions, determine fish hosts, to culture and grow juvenile mussels, with the capability to include endangered species. The facility has produced thousands of juveniles and released most back into the wild. Staff continues to develop methods to rear juveniles and to perform health assessment studies. Very little is known about the husbandry of both adult and juvenile mussels, as well as health status of individuals both in the wild and those held in captivity. Researchers are beginning to get a handle on water quality and its effects on adult and juvenile mussels with regard to ammonia; however, little is know about the effects of nitrite, nitrate and orthophosphate. The Columbus Zoo & Aquarium has an experienced expert staff with regard to water quality maintenance, filtration, and aquatic animal husbandry. Additionally, zoos and aquariums reach millions of visitors each year by highlighting aquatic conservation and research efforts.

The Husbandry of the Striped Octopuses: *Thaumoctopus mimicus* and *Wunderpus photogenicus*

Jay Hemdal
Toledo Zoo Aquarium

In My Eye: Common cuttlefish, *Sepia officinalis*

Alan M. Peters and Nancy C. Boedeker
Smithsonian's National Zoological Park

Common cuttlefish, *Sepia officinalis*, eye conditions and mantle lesions are still a management concern for aquarist and health professionals in public aquarium and zoo facilities. Cuttlefish life cycles were studied extensively prior to the 1980s. It was not until the 1980s that the cuttlefish began to proliferate in U.S. public facilities like Monterey Bay Aquarium and Steinhart Aquarium in California, Waikiki Aquarium in Hawaii, New York Aquarium, Seattle Aquarium in Washington State, and Smithsonian's National Zoo Invertebrate

Exhibit in Washington, DC. Management of cuttlefish has ranged from large groups to single animals. Treatments have ranged from nitrofurazone baths, intramuscular injections of chloramphenicol, and to less invasive oral consumption of enrofloxacin via food. This is a preliminary comparison of treatments and eyeball look at these persistent conditions.

Collection and Transportation of the Tiger Shark, *Galeocerdo cuvier*.

Forrest A. Young and C. Ben Daughtry

The tiger shark is a very challenging husbandry candidate in all aspects from collection to eventual husbandry. Specific individual challenges will be discussed in detail along with transportation method and initial husbandry suggestions.

A Long Distance Transport of a Sub-Adult Bull Shark, *Carcharhinus leucas*

Kari Olson
Aquarium of the Pacific

Husbandry and Captive Propagation of Zebra sharks, *Stegostoma fasciatum*

Lise Christopher, Heather Thomas, and Caryn Poll D.V.M.
John G. Shedd Aquarium
(also see article in current issue of Drum and Croaker)

The zebra shark, *Stegostoma fasciatum,* is a popular species of shark for exhibition at public aquaria throughout the world. Although widely kept for display, only a few institutions have successfully bred this species in captivity. Zebra sharks continue to be in high demand despite being listed as vulnerable on the IUCN Red List. For this reason, they have become a focus of our breeding efforts.

In 2003, Shedd Aquarium acquired a pair of adult zebra sharks who were collected off the northeast coast of Australia. In 2004, we began seeing egg production that has resulted in a total of 79 successful hatchings to date. Our pups have been distributed to fifteen different zoological institutions and aquariums within the United States.

Despite these initial successes, we have also encountered a number of challenges with rearing the young. Over the past four years we have worked on improving and refining our husbandry techniques and preventive health care, including the use of routine, hands-on examinations for the adult population and ultrasound monitoring of egg development. In addition, institutions that have received our offspring have been supplying us with developmental data that we hope will provide insight and further our knowledge.

This presentation will outline general husbandry techniques used in breeding and rearing this species.

What Were "They" Thinking?
Two Exhibit Renovations at the Texas State Aquarium

Sally Hoke
Texas State Aquarium

Recently the Texas State Aquarium renovated two exhibits– *Nearshore* and *Turtle Cove*. Each exhibit was radically changed within the confines of the existing footprints.

Nearshore renovations occurred in Fall 2007 and required taking the tank down to the bare floor to repair leaks. Obstacles during renovation included removing 3 dump truck loads of sand from the exhibit, getting a bobcat in and out of the building, removing a solid concrete sand dune, moving 1500 pound acrylic panels up and down our entry ramps, and repairing the leaks. The entire exhibit was reworked. The new exhibit features a beach for shore birds, a dock for staff access and more room for fish. Care was taken to remove old operational headaches, which has decreased workload for staff. Most importantly, the exhibit is now water tight – we hope.

Turtle Cove renovations were due to aesthetics as well as operations. In the beginning, there was no way for staff to access the exhibit. The top 4 – 6' of concrete tank walls, which are 12" thick, were cut off, removing the top half of the tank. A fabricated sand dune was also demolished. Although we lost 12" of water depth, we were able to increase water volume and swim space for turtles. The life support system was upgraded with addition of ozone. Safe access for staff now exists. Guest experience has improved dramatically with better viewing of animals, graphics and wayfinding. The new *Tortuga Cay* opened in March 2008.

Challenges with Suspected Bacterial Meningitis in Captive Born Bonnethead Sharks

Ashley Ayres
Dynasty Marine Associates

Effects of Chloroquine Diphosphate and Rate of Drug Breakdown Freshwater

Tiffany Adams and Tess Capen
John G. Shedd Aquarium

Fish Recompression Therapy on a Budget – Design and Medical Applications of a Homemade Hydrostatic Chamber

Brian D. Nelson, Senior Aquarist
Pilar J. Gibson, Biologist
New England Aquarium, Central Wharf, Boston, MA, 02110

Based on original designs of units built by Shedd Aquarium and utilized onboard the *R/V Coral Reef II*, we developed a chamber at the New England Aquarium designed for recompression of animals collected at depth. The unit is the result of efforts to increase the volume of the chamber, thereby expanding its ability to contain more or larger animals while keeping the costs reasonable and safety concerns at a minimum. The chamber presently in use at the New England Aquarium is being utilized primarily for medical purposes.

The pressure vessel of the unit is constructed of an Ocean Clear™ canister filter epoxied to a 3' section of 8" clear PVC pipe, while the water circulation and hydrostatic pressure is powered by a Shurflo

120v wash-down pump. The associated plumbing configuration has been modified to deal with variations in the capacities of the pump models and to make the unit more user friendly and adaptable to a variety of holding systems throughout the aquarium.

Although the chamber has been used to treat buoyancy problems in fish, its primary therapeutic utility at the New England Aquarium the last few years has been to recompress fish that have been afflicted with exophthalmia or buphthalmia. The modifications of the plumbing of the unit have allowed more flexibility in treatment duration and location. As a result of these modifications, we have experienced generally more success in treatment outcomes. By incorporating recompression therapy with other treatments, such as drug therapy and aspiration of gas or fluids, fish may have a fair chance at recovery.

Captive Breeding of the Zebra Pleco, *Hypancistrus zebra*

Dan Lorbeske
John G. Shedd Aquarium

As the Zebra Pleco has become a very difficult, if not very expensive acquisition, I have worked with them over the past five years to try to stimulate reproduction in the small group that we have. In August of 2007, and on my third set up with this group, we had our first fry from our three adults housed in a one-hundred and fifty gallon enclosure and since have had six other groups of fry so far yielding fifty-two young plecos. During the time I have been recording the temperature and pH of the system had have noticed a correlation between a slight temperature increase and a spawning event. I would like to share the information with others in the community who may wish to work with these animals, as well as look into exchanging fry for unrelated animals to mix into my group.

Tuesday, June 18

Misc Topics – Off Site at Mystic Marinelife Aquarium, Mystic, CT USA

Post-Hatch Caloric and Nutritional Value of *Artemia salina*

Jessie Sanders
Mystic Aquarium

In aquatic animal collections, such as those in the collection of Mystic Aquarium & Institute for Exploration's Fish & Invertebrate department, live food is an essential part of the diet of animals that are on display, used in education, and kept in reserve for exhibits. For Mystic Aquarium's Fish & Invertebrate department, newly hatched *Artemia salina*, or brine shrimp, are fed to an assortment of fishes and invertebrates. Hatch brine is an important source of fatty acids, which are essential for proper growth and development. Fertilized brine shrimp eggs, encapsulated in a cyst form, are decapsulated and finally hydrated, after which *Artemia* nauplii larvae hatch. After hatching, the nauplii larvae rely on their yolk sac for nutrition. As they use this yolk sac, the hatch brine lose nutritional value and caloric value. Preliminary experiments demonstrated that variation in percent moisture and percentage of empty cysts/ unhatched nauplii in the sample skewed caloric values. Thus, modified sample-collecting techniques were used subsequently. The purpose of this experiment was to quantify the caloric value by percent moisture, percent ash, percent lipid, and percent protein of hatch brine over six hour intervals between 24 and 48 hours post-hatch. The results from this experiment showed a decrease in caloric value of approximately 30-50% between 24 and 48 hours post hatch.

The standing procedure for the Fish & Invertebrate Department is that hatch brine are fed to collection animals 48 hours post-hatch. Therefore, in order to increase caloric and overall nutritional value from the live *Artemia* that are fed to collection animals, the brine shrimp should be fed out earlier than the standard 48 hours, preferably as soon as they are hatched.

Secore 2007 – From Collection to Colonies

Mitch Carl
Omaha's Henry Doorly Zoo

The Set-up and Maintenance of a 2,000 Gallon Temperate Macro Algae Exhibit at Atlantis Marine World

Chris Paparo
Atlantis Marine World

Too often marine macro algae are only considered to be part of an aquarium's filtration system. They are tucked deeply away in a refugium under ones aquarium, never to be shown as proudly as the main tank. Many of these algae are extremely beautiful, and deserve their own display. Although they do pose some challenges in keeping them, it can be done. In this PowerPoint presentation, I will share with you how I set-up and care for a 2,000 gallon a North Atlantic macro algae exhibit.

Getting Out There and Bringing the Classroom With You.

Allan Marshall
Pittsburgh Zoo & PPG Aquarium, Pittsburgh PA 15206, USA

Communications technology is ever expanding, improving and becoming more affordable. Ice Axe has been using satellite phone and internet connections to provide real-time access for students, as well as the general public, to monitor the activities of explorer/adventurers during expeditions to remote parts of the world. The Pittsburgh Zoo & PPG Aquarium has teamed with Ice Axe to provide innovative, educational opportunities to schools around the USA. They can follow the adventures of Zoo personnel as they participate in field research and conservation programs. The schools are encouraged to hold assemblies during which, the field personnel can talk to the children and answer questions they may have. Photos, video clips and an ongoing journal are updated daily and available online so that students can track the progress of the expeditions, providing cutting edge distance learning.

In January 2007 the Pittsburgh Zoo & PPG Aquarium went with Ice Axe to the Amazon where they participated in Project Piaba. Daily updates were posted and scheduled live presentations were performed for 7 elementary schools around the USA. Other expeditions include trekking to the North- and South- Poles and exploring Antarctic aquatic life. This presentation is designed to encourage involvement of public aquaria in these expeditions via direct participation and/or assistance with presenting direct satellite links to local schools.

Tuesday, June 19
Misc. Topics

The Trials and Tribulations of Raising Large Numbers of Hatchling Turtles

Erin Horn
Hofstra University

Raising small quantities of turtles is quite common in aquarium and laboratory settings, which has led to a plethora of resources on how to raise anything from box turtles to sea turtles. However, rearing large numbers of turtles poses additional problems, particularly in a research setting that requires standardized conditions. In this experience, 500 diamondback terrapins (*Malaclemys terrapin*) were hatched and reared for nine months. An integral part of many research projects include a growth study, which can easily be skewed by various parameters that a caretaker or researcher may overlook. The first issue considered was whether to house the hatchlings individually or in groups, and the pros and cons of this controversial decision will be explored. It is important to identify individuals, whether used for display or research purposes. Marking terrapins, which reside in brackish water, proved to be a unique challenge. An innovative tagging repertoire will be discussed that may be used with other types of turtles, including sea turtle hatchlings. Other challenges that will be explored include the following: feeding and diet, overwintering, cannibalism, and release.

Husbandry and Conditioning of *Rhina ancylostoma*, Bowmouth Guitarfish

Nikki Grandinetti and Pam Montbach
Adventure Aquarium

Rhina ancylostoma, Bowmouth Guitarfish are indigenous to the Indian and West Pacific Oceans and can be found along coastal areas and coral reefs. They are usually found above sandy or muddy bottoms where their main diet is crustaceans and mollusks. Bowmouth Guitarfish are named for their large distinctive bow shaped jaw. Adventure Aquarium acquired 1.2.0 *Rhina ancylostoma* in March and April of 2007 from a collector in Taiwan. Upon acquiring the three bowmouth guitarfish, Adventure Aquarium went through a conditioning process to wean them from live foods and to introduce them to target training. Since their arrival, they have received routine physical exams to monitor their health and growth. Detailed feeding and morphormetrics records have been kept on each individual. They have been conditioned to respond to their target at any area in the exhibit and to swim into an adjacent holding area for their routine exams. Our future goals are to condition the bowmouth guitarfish to swim into their stretcher to allow for easier handling during physical exams.

Apple and Oranges: Why are Short Supply Chain (SSC) Fish Better?

Kevin E. Gaines, G. Christopher Buerner
Quality Marine

There are thousands of wild caught marine fish imported daily from all over the world for use in public and private aquariums. It is often a mystery as to how these fish have been collected, held and transported throughout their journey to their new homes. As collectors search further and further out into the ocean from

their holding stations, fish are becoming subject to longer boat trips and subsequent stress throughout the process. While some species are especially vulnerable to long transit times, other species are subjected to unnecessary chain of custody delays. Most delays are so that some overseas wholesalers can increase their assortment by offering fish that do not naturally occur in their local areas or even in their own country. The key to quality marine fish and sustainable collection is short supply chain (SSC) animals. Fish and invertebrates that are collected within a short distance from where they are exported have a huge advantage in fighting disease, being fed properly and surviving transport. While all wild caught marine animals traded in the ornamental industry are not logistically SSC candidates, many high volume species can be sourced through a limited number of SSC vendors. Knowing which ocean, what depths, diets and other critically important biological information is only part of the key to long-term success. In addition to supporting responsible mariculture, dealing with a supplier that sells as many SSC species as possible is the most sustainable choice an aquarist can make.

The Development of Public and Private Aquaria in the Middle East

Francis R. Yupangco
Issham Aquatics, Jeddah, Saudi Arabia

Over the past several years there has been a boom in the construction of large aquariums in the Middle East (Saudi Arabia, United Arab Emirates etc). To many in the North American aquarium industry, the work being done in the Middle East remains an enigma with only the occasional job posting brining the region into brief focus.

Few people are aware that both World's largest residential closed system saltwater aquarium (1.5million Liters) and the largest residential aquarium complex (2 million liters) are currently operating in Saudi Arabia. The design, construction, animal collection and husbandry procedures at some of these unique facilities will be discussed; the first public aquariums in Saudi Arabia and the United Arab Emirates will also be overviewed.

Highlighting some of the projects in the region will help lift some of the mystery surrounding the facilities and people involved in the growth of the aquarium industry in this rapidly expanding area.

Creating Your Own Savage Garden: Carnivorous Plant Bog

Todd Gardner
Atlantis Marine World

POSTER ABSTRACTS

New at the School: An Aquarium Science Program Up-date

Bruce Koike[1], Marion Mann[1], Tim Miller-Morgan[2] and Jane Hodgkins[1]
Oregon Coast Community College

With funding secured in 2003 from the National Science Foundation (grant # 2020141), a specialized curriculum was developed to teach the skills and knowledge necessary to succeed as an aquatic animal husbandry specialist. This content area forms the core of the Aquarium Science Program offered at Oregon

Coast Community College. Two study options are available: a 1 year certificate and a 2 year degree. To date, 30 individuals have graduated from the program and 10 have been hired in the profession before completing their studies.

Breed a Cichlid; Save a Species

Rebecca Leitner
Moody Gardens Rainforest

In December of 2006, Moody Gardens became an active member of the Lake Victoria SSP program. The rainforest received a shipment of four species of Lake Victoria cichlids from the Columbus Zoo. Since the inception of the program over 700 cichlids have been bred from the original brood stock of 819. This constitutes a 60% increase in the population of *Haplochromis sp.* or Two Stripe White Lip within the SSP. This poster provides an overview of the breeding set up, population growth, and future plans for the SSP program at Moody Gardens.

Season of the Jellies

Vincent Levesque
Birch Aquarium at Scripps

Abstract: A poster presentation showing the seasonal patterns of several jelly species found in San Diego. Also included will be anecdotal observations and conclusions, based on seasonal collections, of an invasive jelly that occurred in Mission Bay for five years then abruptly disappeared. Data included will be that of actual collections, confirmed sightings and unconfirmed reports by locals who posses a working knowledge of our local animals.