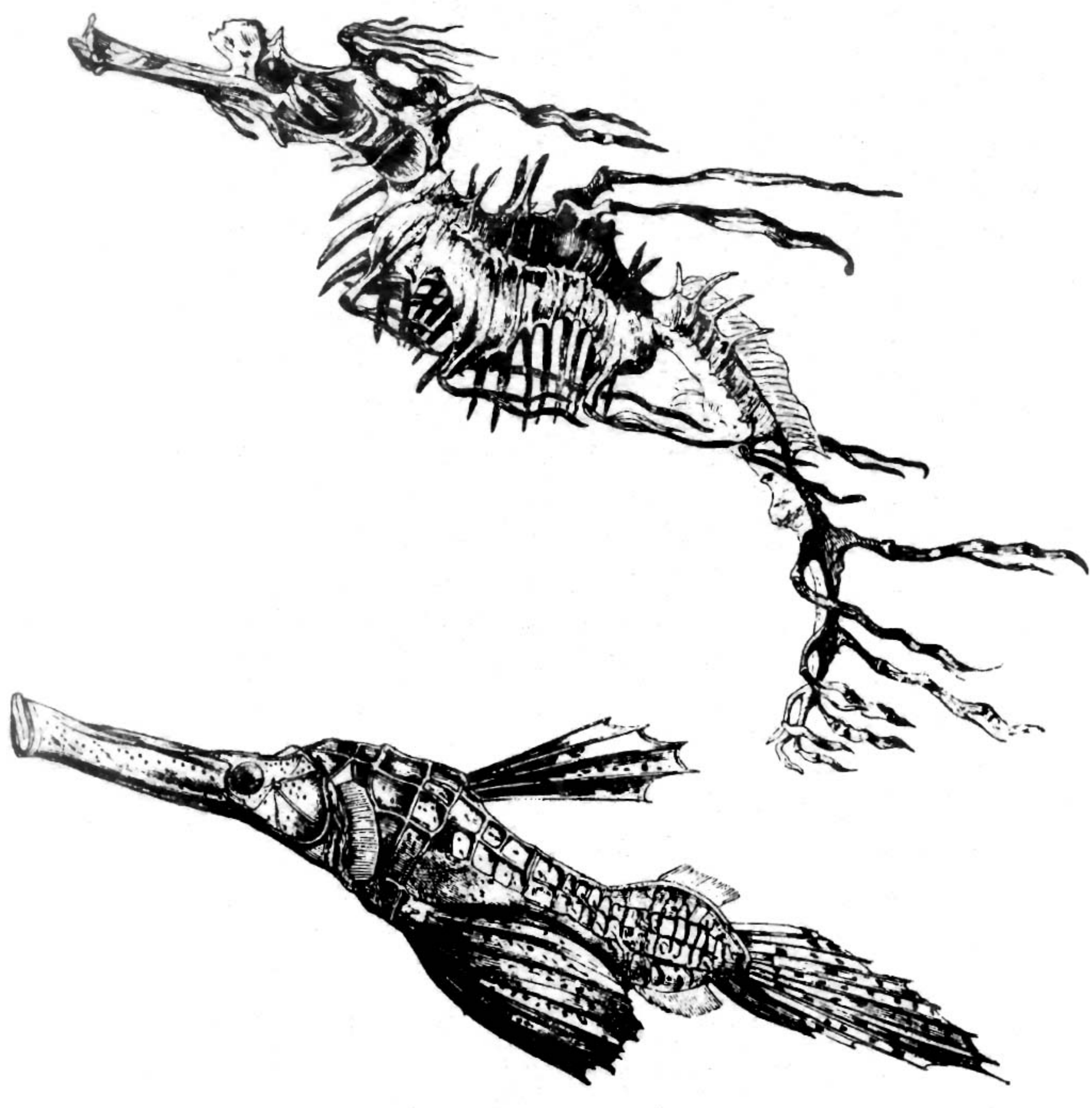
DRUM *and* CROAKER

A Highly Irregular Journal for the Public Aquarist

Volume 27 *Feb. 1996*



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ACKNOWLEDGMENTS

Special thanks go again to Aniko Allen (Sea World of Ohio) who had to deal with a whole new software package just as she began to reformat articles for this issue. Rick Segedi (Cleveland Zoo) again compiled the “35 Years Ago” section. Jay Hemdal (Toledo Zoo) represented Drum and Croaker at the Regional Aquatics Workshop. George Benz (Tennessee Aquarium) provided the guide to authors for the new “journal-style” format option.

“NOT RESPONSIBLE”

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

We assume that the submission of any contribution to Drum and Croaker has been approved by all original authors or co-authors.

Newfoundland *Freshwater* Resource Centre

Pete Mohan
Drum and Croaker

Dec. 8th, 1994

Dear Mr. Mohan,

I realize the date has past for articles for your journal, if so this may be considered for your next issue.

My reason for writing is that our facility has advertised in the past that we were the only **"year round public fluvarium in North America".** This may have been researched in 1990.... details are scanty and it's time for an update regardless . Through your journal we would like to try and verify this statement, make any necessary changes or desist in using it altogether. The definition of the word fluvarium may be the key to this issue.

Wording is somewhat specific, the Newfoundland Freshwater Resource Centre is open **"year round"** and has been, since it opened to the **"public"** November of 1990. The NFRC is a project of the Quidi Vidi \ Rennies River Development Foundation, a charitable organization registered in 1985. The Foundation is committee driven by volunteer members and carries a full time staff of seven. The Fluvarium, as it is most commonly refereed to, is an education facility, for youth and school groups, and is a local resource for the public.

"Fluvarium", our definition, is a natural living stream with viewing windows.

A channelized section of Nagles Hill Brook was reconstructed to form pool and riffle habitats. Our facility consists of three levels, the first level having viewing windows into one side of the brook. The habitats were created and the system left to naturalize. Fish, birds, mammals and other creatures are free to move in and out of the viewing section at will. Within the Rennies River watershed, the Fluvarium is on a tributary of one of the headwater streams and has been used by Brook trout *Salvelinus fontinalis* and since the 1880's the Brown trout Salmo trulta for spawning each fall. Each spring muskrat, mink and osprey are sighted on a regular basis as they seek out nesting areas. Winter months the water is at ,it's clearest, surface water frozen and below, little movement within the metre deep pools. The brook can be viewed through the, seasons as a living system with minimal interference by us humans.

The Fluvarium is not a government run operation, nor is it a business venture in tourism or a research facility. Our aim is to educate the public by giving them a unique view into a living system.

The questions then would be; Are there other fluvariums? maybe other definitions? possibly no definition. Through your readership we would like to pose these questions. I look forward to suggestions on how to present this to best fit the format of your journal. Maybe an invitation to similar facilities to contact us or a calI for the definition of the word fluvarium itself. Any help would be greatly appreciated.

Brian Penney
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Drum and Croaker 35 years ago (almost)

by Rick Segedi

Cleveland Metroparks Zoo

We do not have a copy of D & C in our collection from 1960; perhaps there was none. Instead here is an excerpt from an editorial by Lee Finneran, then Curator-Director of the New England Aquarium, and editor for the October 1961 issue.

Would you feature and exhibit with no animals showing? Would you have one in your operation? Is it a matter of your personal choice? What is the reason for your institution?

We are very prompt to assure each other that we are not in the menagerie business, that we are not just keeping animals, that our operation has a mission. Some of us fumble on coming up with purposes.

Many animal collections are a sort of personal barony. The inventory and interpretation, if any, represent the whims of the director. Perhaps this is one reason why animal management and interpretation people do not have a strong vehicle of communication. At this time, there is no agency for transmitting and keeping specific professional information. The serious question of professional affinities has not been solved. When are we going to apply ourselves to these problems?

Angus Wilson's new fiction work, "The Old Men at the Zoo.' sometimes [sic] about the organization and administration of a zoo in the period of 1970-73 discusses raison d'etre for collections of animals. Esthetic, research, conservation, civic responsibility and entertainment are mentioned.

This prospect that modem animal keepers will still be searching for modem policies and objectives ten years from now may have much truth to it. Where the hell are we going, boys?

Would you set up an exhibit which did not show the animal in plain view? You would have to if you were giving a presentation of protective coloration or defense mechanisms. But how many of you are interested in presenting biological principles?

In fact, how many zoos and aquariums today tell the visiting public the basic definition of an animal or more specifically of a mammal, bird, reptile or fish?

Other items of interest

Rhode Island Oceanarium, Inc. Has one in plan for a projected $550,000. This show will be located in Saunderstown, Rhode Island.

Philadelphia Aquarium, Inc. Has one in plan for a projected $2,000,000. This show will be located in downtown Philadelphia.

A directory of public aquariums of the world is being prepared . Contact: Spencer Tinker, Director, Waikiki Aquarium, 2777 Kalakaua Avenue, Honolulu, Hawaii.

Every public aquarist should get to see The Seven Seas Panorama exhibit at Brookfield Zoo in Chicago. It is quite a construction.

CONSTRUCTING SMALL AQUARIUMS
SOME ALTERNATIVE IDEAS

Stephen Walker, Curator of Aquaria

Tulsa Zoological Park, Tulsa, Oklahoma

Wooden Tanks

Plywood aquariums have been in use for decades. Usual construction involves the application of numerous layers of epoxy or polyester resins, often with glass mat or fibers imbedded to increase strength. Unfortunately this process can be laborious, messy, and produces unhealthy and noxious fumes.

At the Tulsa Zoo, we employ a simple method for constructing plywood tanks for holding, filters, and displays and, using this technique, have had tanks in service for up to 10 years without a single failure! The strategy is simple. Instead of coating the plywood, we laminate it with polyvinyl chloride (pvc) sheet to render the tank walls waterproof. The wood for construction should be a high grade plywood. We use a type known as *medium density overlay* finished on both sides (MDO - 2GS). This material is designed for outdoor signs, and is relatively water resistant even before a waterproof agent is applied. The pvc sheet is available in several thickness, and is sold in 4' by 8' sheets as "type-1". We have found that the thinnest available, the 1/16" thick stock, is perfectly acceptable, and that the gray color makes an attractive neutral background. The plastic is glued to the wood using a contact cement such as Formica® glue and must be applied *before* cutting the wood in order to create overlapping joints in the finished tank. The laminated wood and plastic sheets can then be cut and assembled into the desired size aquarium. The final and perhaps most important step is to seal the inside seams of the tank. Most silicone sealants will not adhere well to pvc and can not be used alone. The solution is a product made by Dow Corning® designated primer "1205." This fast-drying clear liquid is painted on the plastic and allows standard silicon rubber sealant to adhere to the pvc as well as it does to glass. This product is magic stuff, and we continue to find more uses for it.

Stock Tanks

Another product we have found multiple uses for is Rubbermaid's® line of plastic stock tanks. These are designed as water troughs for livestock, but make excellent rugged holding tanks, are quite inexpensive, and are available in sizes from 50 to 300 gallons . This may not be news to most, but we have been able to modify the tanks to make them more useful. Since it is difficult to assess the status of aquarium specimens merely from a top view, we add side view panels to the stock tanks. This is easily accomplished by using a saber saw to remove a flat panel and replacing it with ½" acrylic sheet. Once again, the 1205 primer is employed with silicone to assure a tight seal. Since the stock tanks flex some when filled, glass should not be used.

Fiberglass Tanks

Another alternative technique we have used is a method for sealing fiberglass aquariums. Recently, we acquired a 2,300 gallon round fiberglass holding tank (Red Ewald, Inc) which is supplied in a multi sectional form ready for assembly. The sections are bolted together and the seams are supposed to be sealed using fiberglass mat and resin. Since we were installing this tank in a basement, we were worried about ventilating the area during the fiberglass process. We went back to our old friend 1205 and we were able to seal the seams successfully with black silicone rubber. This procedure was infinitely easier than the fiberglass process and the tank was ready to go in 24 hours. The system has been up and running for several months with no leaks or problems.

Sealants

One final observation is that all silicone sealants are not alike. We use Dow Corning's "795" silicone building sealant and have found it superior to most other products. It costs more and is not available in clear, but has excellent adhesion, tolerates joint movement of ±50%, and is a neutral cure product (does not use acetic acid to stabilize the sealant). It also has excellent tooling properties and its high viscosity makes it easy to apply in awkward situations.

SOURCES FOR MATERIELS

Dow Corning Corp., Midland, Michigan 48686-0994
Rubbermaid Products, Inc., 3124 Valley Ave., Winchester, Virginia 22601
Red Ewald, Inc., P.O. Box 519 Karnes City, TX 78118-0519. (800) 531-3606

Figure 1. Products discussed in the text - Dow Corning Sealant 795, Contact Cement, and Dow Corning's 1205 primer.

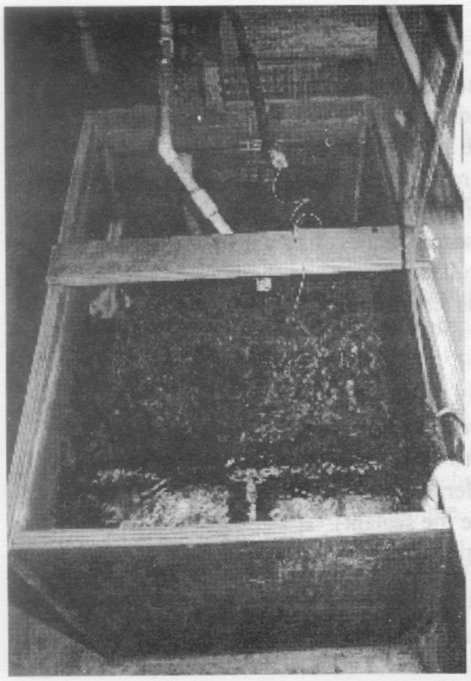

Figure 2. Plywood and pvc filter box with chiller.

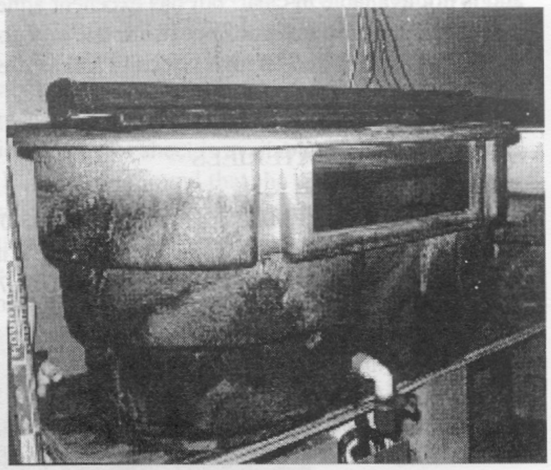

Figure 3.
Rubbermaid 100 gallon plastic stock tanks with viewing windows.

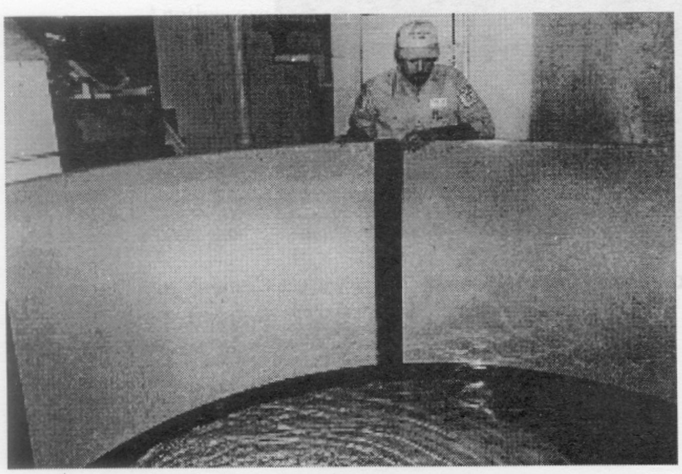

Figure 4. 2,300 gallon fiberglass holding tank with joints sealed with silicon rubber.

SEDATING AND EUTHANIZING OCTOPUSES

Roland C. Anderson, Biologist

The Seattle Aquarium

I have recently been asked by some other aquariums what is the best or most humane method of euthanizing an octopus. I have heard four reasons for putting down an octopus. The most common reason is that the animal is at the end of its life span. Aquariums may display brooding female octopuses guarding their eggs, but sometimes females live on after the eggs hatch (normally females die right after the eggs hatch). Such females generally have stopped eating and are in a state of decay, unacceptable as display animals.

Contrary to popular belief, most male octopuses do not die directly after mating. They do eventually die since they are terminal spawners (one of our educators likes to point out that there is no way for these animals to practice "safe sex"!), but they may live several months before dying. Like the females, they may not eat during this period, known as "senescence." They usually come out of their dens and become very active, even during the day. It has been hypothesized that this frees up den space for females to lay their eggs in. Such senescent males are usually good display animals; they're active and require little care since they're not eating. But because they're not eating their tissues soon start to decay and they usually develop "ulcers" on their mantles as part of the aging process. Once the ulcers appear such animals are not display quality and could be put down.

Octopuses in captivity generally do not heal from wounds as well as those in the wild, especially those in closed systems. It may be necessary to euthanize an animal that has injured itself severely. And it may be necessary to euthanize an octopus for scientific purposes. I recently supplied a taxonomist with an Octopus rubescens that was close to 400 g in weight. This is about twice what a normal red octopus gets. The taxonomist wanted it sedated, euthanized and fixed in formalin.

All of the above reasons require a quick humane method of euthanizing an octopus. Roper and Sweeney (1983) list five methods of anesthetizing cephalopods, several of which are also suitable for euthanization. Their first listed agent is ethanol (ethyl alcohol). They say ethanol in a one percent solution will induce sedation in one to two hours; I've found it to work quicker on small octopuses (< 1 kg), within 30 minutes. This method works well to examine, manipulate or operate on an octopus and the animal will recover in pure sea water. I've also used ethanol as a euthanizing agent. I gradually increased the percentage to about five percent ethanol and left it for several hours, killing the animal painlessly. This is effective for euthanizing a small octopus but will be prohibitively expensive for a large species such as O. dofleini.

Roper and Sweeney's second method is cold water. They state this works especially well for tropical species, which are sedated at temperatures of -1.9°C to 4°C (-1.9°C is the freezing point of salt water). I've found that freezing octopuses in water works well to euthanize them.

They just move slower and slower until they stop and die. This method works particularly well for large species such as the giant octopus, which can be placed in a large barrel of water and moved into a large freezer until frozen and dead. There are other authors who feel freezing may not be a humane way to euthanize an animal, specifically for poikilotherm vertebrates such as reptiles and amphibians (see Andrews, 1993; Burns and McMahan, 1994). These authors suggest that in reptiles and amphibians ice crystals may form in tissues causing pain; they recommend against this method in such animals. While freezing may certainly cause discomfort or pain in a reptile, I've noticed no such reaction in octopuses and I feel this is the method of choice for large octopuses until we learn differently.

Roper and Sweeney's other methods are the use of fresh water, magnesium chloride, or urethane (ethyl carbamate). I have not found fresh water or $MgCl_2$ to work very well as anesthetizing agents for the octopuses I have available (O. dofleini and O. rubescens). My experience showed the addition of fresh water seems to agitate the animals and cause peculiar arm contractions. $MgCl_2$ does not seem to slow down octopuses at all, even at high concentrations. Fresh water and $MgCl_2$ may work differently on other octopus species. Urethane is a carcinogen and shouldn't be used casually.

I have tried the fish anesthetic quinaldine in an alcohol solution on octopuses. This does not sedate them at all, but rather irritates them tremendously. While using quinaldine in the wild to extract crevice-dwelling fish, we have frequently observed it to force octopuses out of their dens. The fish anesthetic MS222 likewise agitates octopuses and also causes arm contractions similar to those caused by the use of fresh water. I haven't tried benzocaine on octopuses but Brown (1988) recommends it as an inexpensive euthanizing agent for fish.

In summary, freezing is my method of choice for euthanizing an octopus, especially tropical species, and overdosing them on alcohol is a good second choice for smaller species. In other words, a well-shaken dry vodka martini would definitely put an octopus under permanently.

Acknowlegdments:
I am grateful to Dr. Janis O. Joslin, veterinarian of the Woodland Park Zoo, for reviewing this paper and providing valuable suggestions and references.

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FABRICATION OF NATURAL-LOOKING FIBERGLASS BACKDROPS AT THE SEATTLE AQUARIUM

Roland C. Anderson, Puget Sound Biologist

The Seattle Aquarium

The Seattle Aquarium has 47 small tanks displaying Puget Sound fish and invertebrates. Before the Aquarium opened in 1977 it was decided to place natural-looking backdrops at the rear of these tanks. The purpose of these backdrops was to give the tanks a semblance of rock backgrounds making the exhibits look more natural and to give habitat for the animals to crawl on, swim over, or cling to. The use of these backdrops also allows them to crawl or swim upward from the bottom making a more interesting three-dimensional exhibit.

Various materials have been used to make backdrops in aquarium tanks. For ease of construction, easy placement and durability it was decided to use fiberglass in these small (42-432 gallons) tanks over other materials such as concrete, plastic or silicone. Such fiberglass backdrops were made and installed as needed before the Aquarium opened. Backdrops for larger tanks were constructed of concrete. Since opening to the public a number of the smaller tanks in the aquarium have been fitted with backdrops made of black or dark blue acrylic sheets. These have been put into tanks containing primarily animals that live on the bottom such as eelgrass animals like tubesnouts or geoducks, or animals swimming in the water column such as jellyfish.

Tank arrangements and sizes have changed several times since opening, necessitating re-making the backdrops. To date, we have made such artificial fiberglass backdrops three times in the history of the Aquarium, the latest this last year.

The procedure in making these backdrops is as follows. A latex rubber mold of an actual rock wall is made. The latex mold should be several times larger than the backdrops needed. At the fabrication facility two frameworks are clamped together sandwiching the latex mold. Fiberglass resin is then painted onto the mold in several coats to approximately one half inch thick, allowed to dry, and popped out, almost ready for use.

Making the latex mold involves a number of steps. The first step is to choose a site. The site used to make such a mold is very important and should be chosen with care. It should be a rock wall with enough small relief to be interesting and realistic. It should have cracks, crevices and projections. Lichens and mosses are OK in that they give further realistic relief. The rock wall should be easily accessible from the ground or short ladders. It is preferable to find a rock wall that faces the direct sunlight.

The location of the rock wall should be in a dry climate at a place or in a time of the season where it will be very warm and dry for at least a week. In our case, although we could locate suitable rock walls in western Washington, Seattle is known for its rain and unpredictable weather even in the summertime, so we chose to make our latex mold in eastern Washington which is known to be hot and dry in the summer. We recommend doing it in the hottest driest part of summer. One year we made a mold in September and while hot and dry during the day the colder temperatures at night delayed drying of the mold considerably. The first two times we made backdrops we used a site near Leavenworth, Washington. The third time we couldn't gain access to the site previously used so we switched to a site near Entiat, Washington. Precipitation at these sites averages about ten inches a year.

Loose dirt and plants (other than mosses and lichens) must be removed from the wall. When the rock wall is prepped it then needs to be sprayed with silicone spray to ease removal of the mold. It should be a suitable size for the backdrops desired; a realistic size is about six feet by ten feet. We used eight cans (10 ounces each) of silicone to cover an area six by ten feet.

After being sprayed with silicone the liquid latex (brand name Vultex^R) is painted on. The first two coats should be thin coats that are allowed to dry thoroughly before re-coating. The first two coats can be applied on the same day if it is hot and sunny. Thereafter succeeding coats should be allowed to dry a minimum of a day before re-coating, and preferably more than a day. The first two coats of liquid latex can be painted on just as it comes from the can but succeeding coats should be thickened. We used Cabosil^R to thicken the latex to a consistency of thick cream. Cabosil^R is a very fine powdery substance consisting of powdered silicon. Succeeding coats of latex are painted on until a thickness of at least a half inch to an inch is achieved.

A cautionary note should be inserted here. Both liquid latex and Cabosil^R are hazardous substances and appropriate safety precautions should always be taken when using these substances. We used gas masks while painting the latex and tight-fitting goggles when mixing in the thickener. Fumes from the latex can also affect eyes.

After thorough drying of several days the mold can then be carefully peeled off and stored until used. It should be stored flat - folds in it will cause permanent creases - and nothing should be stored on top of it. The mold can sit for two to three years but if stored beyond that the latex will lose some of its surface relief. While still useable it will not produce as interesting a backdrop.

To make the actual backdrop two wooden frames need to be constructed. The inside of the frames must be the exact length and width of the desired backdrop. These can be made of two by four lumber. An area of the latex mold with interesting surface relief is sandwiched between the frames and clamped down tightly. The surface of the mold and the edges of the two by fours are then sprayed copiously with silicone spray. The mold should be supported underneath to prevent sagging. Various projecting objects can be used for support to give more relief to the backdrop.

The first coat of fiberglass is the color coat. The resin and the hardener are mixed together and the coloring agents are added, purchased specifically for coloring fiberglass resin. We mixed colors together empirically until the "right" color was achieved, this being a rock-colored brown or dark gray. We tried making some backdrops in shades of dark blue and green and these did not look natural.

We used one gallon of fiberglass resin per coat on the backdrop, covering an area 36" by 42". When painting the fiberglass on we tried not to get much of it on the wood frames. Disposable pails and paddles for mixing greatly ease the clean-up process.

After the first color coat each succeeding coat was laid down with fiberglass cloth roving to provide additional strength and support. Each succeeding coat was also thickened with Cabosil^{R}. Each coat was allowed to dry and set overnight. The final thickness of the backdrops was about half an inch. Another cautionary note here: fiberglass resin fumes are toxic and should be protected against. Proper respirators should be worn when working with curing fiberglass resin and proper ventilation should be assured of during the curing time. We used a ventilation hood to get rid of noxious fumes.

After the last coat the fiberglass should be allowed to cure for several days before releasing it from the mold. Once released, the sharp edges of the backdrop were sanded off. Then it was placed in running sea water to cure, colonize, and flush away toxicants for about a week. After that the backdrop is ready to be placed in an aquarium tank.

We did not place backdrops on the sea floor to colonize since we have the luxury of running raw sea water to our tanks which thus colonizes the backdrops. Backdrops are colonized quite differently from tank to tank, depending on which animals are kept in the tanks. Backdrops at the Seattle Aquarium are colonized with coralline algae, sponges, tunicates, cup corals, calcareous tube worms, jingle shells, diatoms, kelp and sea weeds, and other marine life.

Tanks can swell when filled with water. If the tank is measured to fit a backdrop when it is empty backdrops may be a bit loose in the tank after water is added. They can be either silicone-glued to the back wall or braced with rocks at the bottom and tied at the top with monofilament.

After years in the water, if such backdrops are taken out of the water to dry they may become brittle and break easily, and they also may crack spontaneously, so it’s best to keep them moist if they’re taken out of the water.

1996 REGIONAL AQUATICS WORKSHOP (RAW)

The next RAW meeting will be held at the New England Aquarium in Boston, Massachusetts. Tentative dates of June 7-9 have been set. Contact Steve Bailey, Curator of Fishes at (617) 973-0297 if there are any questions or conflicts.

BEHAVIOURAL ENRICHMENT ACTIVITIES DEVELOPED FOR THE MARINE MAMMALS AT THE SYDNEY AQUARIUM

Lynne McLachlan
Senior Marine Mammal Keeper

Sydney Aquarium

Abstract:
Sydney Aquarium keepers have been experimenting with different activities to entertain the three female Australian Fur Seals. This has let to the development of an activity which requires skill and intelligence from these aquatic animals.

This activity involves placing fish inside two different types of balls. One type of ball is positively buoyant, the other type negatively buoyant. The three Fur Seals involved in this activity have developed different skills of manouvering the balls to achieve their reward.

The Sydney Aquarium was opened in 1988, the Seal Enclosure was a later addition which opened late in December 1991.

Our seal enclosure is thirty metres long, fifteen metres wide and seven metres deep. Four floating barges are connected together with a large heavy duty vinyl liner suspended in the middle to form the seal enclosure. The special features included in this exhibit are an underwater viewing chamber with a unique glass floor, a floating island that is tethered to the bottom of the pool and a floating service pontoon for keeper access and additional haul-out for the seals.

The Sydney Aquarium currently has three female Australian Fur Seals aged 21, 21 and 19 (*Arctocephalus pusillus doriferus*) and two male Harbour Seals aged 22 and 16 (*Phoca vitulina richardi*). These seals have been at the Sydney Aquarium since December 1991. They were all previously inhabitants of Taronga Zoo (Sydney).

In May 1994 keepers began experimenting with different activities and toys to entertain the Fur Seals. Seaweed, ice, floats and basketballs were all introduced to totally disinterested seals. A basketball was filled with freshwater to make it neutrally buoyant as this made it easy to push through the water. One seal - Averil - pushed the ball once and then lost interest, the other two seals - Ida and Angie - ignored it completely. This led to the idea of a ball with fish inside.

Plastics manufacturers were contacted until a company was located that produces vandal proof street lamps. This company manufactured two types of plastic balls, one ball is made of polyethylene which is white in colour and has a density of 0.93. This material is positively buoyant. The other ball is made of polycarbonate, a clear material that has a density of 1.2 which is negatively buoyant. The company ROTADYNE were very helpful. They gave Sydney Aquarium a thirty centimetre polyethylene ball and later a forty-six centimetre polycarbonate ball to experiment with to see if the seals would respond.

In June keepers began experimenting with a “training ball”. This ball was polyethylene, white in colour, positively buoyant, 30cm in diameter and there were six 5.5cm holes drilled into the ball. The sharp edges were sanded to prevent injuries. The session began by Keepers who were on snorkel taking the ball about five metres below the surface and letting it float up, the water moving through the ball helped to flush some of the fish out. Two of the three fur seals were collecting any fish that fell from the ball. The next day we repeated the exercise. The subordinate animal - Averil - started to push the ball herself but would come to the keepers expecting a reward. A fish was then placed half in and half out of the ball and presented to her. We did this several times and would push the ball at her after she received the fish. It didn’t take long for her to work out the fish were in the ball. The dominant animal - Ida - realised Averil was getting food! Every time Averil managed to get a fish, Ida would steal it. This happened several times until Ida worked out where the fish were coming from and then she would not let Averil near the ball.

Once each of the Fur Seals learnt how to manoeuvre the balls, we then put a portion of their evening feed in the ball when they were penned at night (all fur seals have an individual night pen with a pool). This gave the subordinate animals a chance to improve their skills without the dominant animal interfering. This was the only time their daily food requirement was used in the balls and only then because they were isolated in the pen and another seal wouldn’t steal their food.

When all the Fur Seals were successfully using the polyethylene ball, a forty-six centimetre ball, negatively buoyant and a clear material was introduced. Three 4.5cm holes were drilled into the ball. Both balls were put in the water at the same time, the dominant seal found it hard to patrol two balls at one time, especially when they were put up different ends of the pool, although she would still chase the other seals if she caught sight of them using the other ball.

With the success of the “experimental balls” we then purchased two thirty-eight centimetre polyethylene and two thirty-eight centimetre polycarbonate balls. Two holes were drilled into each ball, each hole being 4.5cm in diameter.

All the balls were put in the water at once, it took seven minutes to empty the training ball, forty to fifty minutes to empty the positively buoyant polyethylene balls and one hour and twenty minutes to empty the negatively buoyant polycarbonate balls (each ball had approximately 15 small yellowtail inside).

Each seal has a different technique of retrieving fish - the most common method is to anchor their nose over the hole and swim around until a fish is felt close to the hole, it is then “sucked” out. Another method is to get the clear balls in mid water and “whack” it with their fore flipper making it spin. Angie our intermediate seal has developed her own original technique of rolling the ball along the bottom of the pool until a fish falls out.

The negatively buoyant balls are harder to use as the seals have to work at keeping them at the surface. It did not take long for Ida to learn to blow air into a hole to form a big bubble in the ball to help it float - the other seals soon imitated this behaviour. It was then necessary to drill small holes all over the ploycarbonate balls to help re-sink them.

If the balls are divided between the surface and the bottom, the dominant seal has less chance of patrolling and controlling them and each seal can participate in the activity.

The seals have become so skilled at retrieving the fish it is an ongoing project of altering the balls to make it more of a challenge for them (it now takes them 10-15 minutes to empty all the balls).

Some changes that have been made are:

- Larger fish so they are harder to get out
- Injecting fish with air so their buoyancy within the ball changes - the fish float in the middle of the ball instead of lying on the bottom of the ball.
- a small piece of tube glued on inside of ball so the fish don't slide easily out of hole.

Another idea still to be implemented is to weight a ball from the inside so that when the seals spin the ball it returns to the same position away from the hole.

The fish ball activity occurs 3-4 times a week on different days so the seals do not learn to anticipate it. All food that is placed in the balls is extra to the seals daily food intake. We weigh our seals once a week and their food is adjusted if necessary. They use so much energy during this activity that the extra food does not seem to affect them.

This behavioural enrichment activity has generated an exciting response from the three fur seals, they are more alert and staff have found them more curious and inquisitive of any new objects placed in the pool, or of any maintenance being carried out by staff in the water.

The animals appear to be more friendly and relaxed and more willing to interact with keepers even when food is not involved.

NOTE:

It should be noted that the Sydney Aquarium seal enclosure is soft sided, the seal pens are concrete and so far there has not been any problems with balls breaking. A close eye should be kept on this activity in rigid pools to ensure no harm comes to any seals if a ball should break.

Editors Note:

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MORPHOLOGY OF THE FISH LOUSE (*ARGULUS*: BRANCHIURA)

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Abstract: *Argulus* is an important and species rich genus of ectoparasites whose representatives are common agents of disease and death in fish populations. Misunderstandings of the morphology of these parasites has historically created a literature which confounds efforts to identify *Argulus* specimens to the level of species. This problem in turn has thwarted efforts to accurately accumulate and successfully utilize species specific life history data for parasite control. Recently, detailed studies have provided a sound morphological foundation for those studying *Argulus* specimens. In this report, a contemporary overview of the morphology of *Argulus* species is given along with a synopsis of valuable techniques used in studying these parasites.

INTRODUCTION

Argulus Müller, 1785 (subclass Branchiura) is an important genus of crustaceans containing some 120 described species that are predominantly ectoparasites of fishes. Commonly referred to as fish lice, various *Argulus* species inhabit marine, brackish, and fresh waters, and globally the genus has a cosmopolitan distribution.

Unfortunately, even cursory examination of *Argulus* reveals it to contain many nominal species with questionable taxonomic status. This situation is not only regrettable because many branchiurans are economically important pests (e.g., see Kabata 1970, 1985), but also because when taken together their distributions can be viewed as an example of how continential drift might influence biogeography (see Fryer 1969; Schram 1986). This in turn suggests some temporal trail markers for Branchiura's existence, and consideration of the origins of parasitic taxa are of evolutionary significance given the great success of parasitism as a trophic lifestyle and the fact that it has been suggested (e.g., see Price 1980; Esch and Fernandez 1993) that parasite species far outnumber free-living taxa and, therefore, make up the bulk of Earth's extant biodiversity.

It is especially difficult for nonspecialists to efficiently study *Argulus* specimens. For one, the literature contains thousands of references to the genus and many of these are relatively inaccessible and/or factually flawed. In 1960, David Causey, Professor of Zoology and renouned carcinologist at the University of Arkansas, wrote a short report for laymen exposing some of the pitfalls in identifying *Argulus* specimens (see Causey, 1960). Causey (1960) was justified in poking fun at the then current state of affairs regarding the identification of *Argulus* specimens. Unfortunately, it has taken more than three additional decades for detailed examinations of *Argulus* specimens to provide information which might eventually help unclog the taxonomic log jam that species within the genus currently represent.

We feel that an understanding of basic morphology is a crucial first step in the successful study of any organism. Therefore, we provide here an overview of the morphology of *Argulus* species in hope of promoting a contemporary understanding of fish lice by aquaculture specialists and aquarists who so often confront them. In reading our report and when studying *Argulus* specimens, it should be remembered that variation in general body form and/or in the appendages or other structures has historically been used to define species of fish lice. Therefore, although a basic body plan definitely exists for these parasites, and it is this basic plan which we will detail here, researchers should strive to observe and document the fine morphological details which denote species identity.

Our own observations of *Argulus* specimens have been important in furnishing the firsthand understanding that underlies this report, however, we have also been duely influenced by recent works of others that provide topical treatments of the genus (see Overstreet *et al*., 1992; Swanepoel and Avenant-Oldewage, 1992; Avenant-Oldewage and Swanepoel, 1993; Gresty *et al*., 1993; Rushton-Mellor, 1994). Because of space constraints we have limited ourselves to consideration of adult morphology of fish lice, however, we refer readers interested in juvenile morphology to works by Tokioka (1936) and

Shimura (1981). We end this report with an addendum detailing some of the more useful methods used to examine fish lice for identification purposes.

Because there is no universal terminology for the various body parts of *Argulus* species we have adopted one of our own. This was done on a structure by structure basis using what we consider to be the most acceptable current information. We have not attempted to justify our choices in terminology. However, because we are only too aware that the study of *Argulus* specimens is somewhat confounded by the historical use of many names for the same morphological structure, we have added in parentheses terms synonomously used by others for our terms. These parenthetical lists of synonomous terms are not intended to be exhaustive.

MORPHOLOGY OF *ARGULUS* SPECIES

Argulus species exhibit body plans which are well-adapted to parasitism. Like other crustaceans they possess a chitinous exoskeleton or cuticle. Their general habitus is dorsoventrally flattened and composed of a carapace, thorax, and abdomen (Fig. 1). The body can be uniformly colored or speckled with pigment (especially the dorsal surface) and the adult female is often more colorful than the adult male (e.g., cf. male and female Fig. 1). Ventrally the body often issues tiny spinules which seemingly must assist in keeping the parasite from slipping over its host. The carapace (Fig. 1) is expanded laterally into a shield-like form and exhibits a frontal region delimited by anterolateral depressions and posterolateral lobes (= alae). Respiratory areas marked by the thin cuticle covering them are located laterally on the underside of the carapace (Fig. 1). Three medially located naupliar eyes and two much larger laterally placed compound eyes are located dorsally on the carapace (Fig 1). The thorax (= trunk) lies posterior to the carapace and is often indistinctly segmented. The abdomen, located posterior to the thorax, is characteristically dorsoventrally flattened, its right and left sides separated by an anal indentation (Fig. 1). Two caudal rami (= uropods) are located along the anal indentation and each bears several setae (Fig. 2A).

On the ventral body surface there are a series of paired appendages and other paired and unpaired structures (Fig. 1). The entire complement of true appendages consists of first and second antennae, mandibles, first and second maxillae, and four pairs of legs. The first five pairs of appendages are found beneath the carapace, while the legs are issued from the thorax (Fig. 1). The first and second antennae are the only true appendages which lie anterior to the compound eyes (Fig. 1). The first antennae (= antennules) are typically four-segmented (Fig. 2B). The first segment is often heavily sclerotized and has a blunt posterior projection, while the second segment forms a strong laterally directed hook (Fig. 2B). Segments of the first antenna beyond the second segment (these segments sometimes referred to as the palp of the first antenna) are typically slender and often armed with setae (Fig. 2B). The second antennae (= antennae) are typically five-segmented (Fig. 2B). Each segment can issue setae, and the first segment often has a large posteriorly directed protuberance (Fig. 2B). Just posterior to the first segment of the first antenna there are one or two postantennal spines (Fig. 2B). *Argulus* species are unique in possessing an anteriorly aimed and needle-like preoral stylet located along the midline just anterior to the mouth tube (see Fig. 1). The preoral stylet (= oral stylet, sting) can be thrust forward into the host and then retracted into a cuticular sheath (Fig. 2C). In fixed specimens the preoral stylet may be extended and visible or retracted within the sheath and not as noticeable. Just posterior to the preoral stylet is the mouth tube (see Fig. 1). The mouth tube (= proboscis) is composed of an anterior labrum and a posterior labium (Fig. 3A), and may be elevated so that its apex touches the host or may be lowered so that it rests within a medial groove of the carapace. The labrum may or may not issue various numbers and types of cuticular scales (e.g., see Fig. 2D). The mandibles (Fig. 2E) are small, contained within the mouth tube, and typically have serrated edges. The first maxillae (= maxillules, suckers) are located on either side of the mouth tube and are often the most conspicuous appendages (see Fig. 1). The terminal suction cup-like segment of each first maxilla is strengthened by rows of supporting rods about its circumference (Fig. 2F). Each supporting rod in turn is composed of a number of sclerites which are stacked atop one another (Fig. 2F). Posterior to the first maxillae are the second maxillae (= maxillae; sometimes the second maxillae are erroneously referred to as maxillipeds). Each second maxilla is five-segmented (Fig. 2G). The basal segment (= basal plate) is robust and usually has a number of stout posterior projections as well as a region armed with cuticular scales and/or spines (Figs. 2G, 3C). Segments two-five are more slender and may also issue scales and/or spines, and usually the terminal segment is apically armed with a number of projections and/or claw-like spines (Fig. 2G, 3E). At

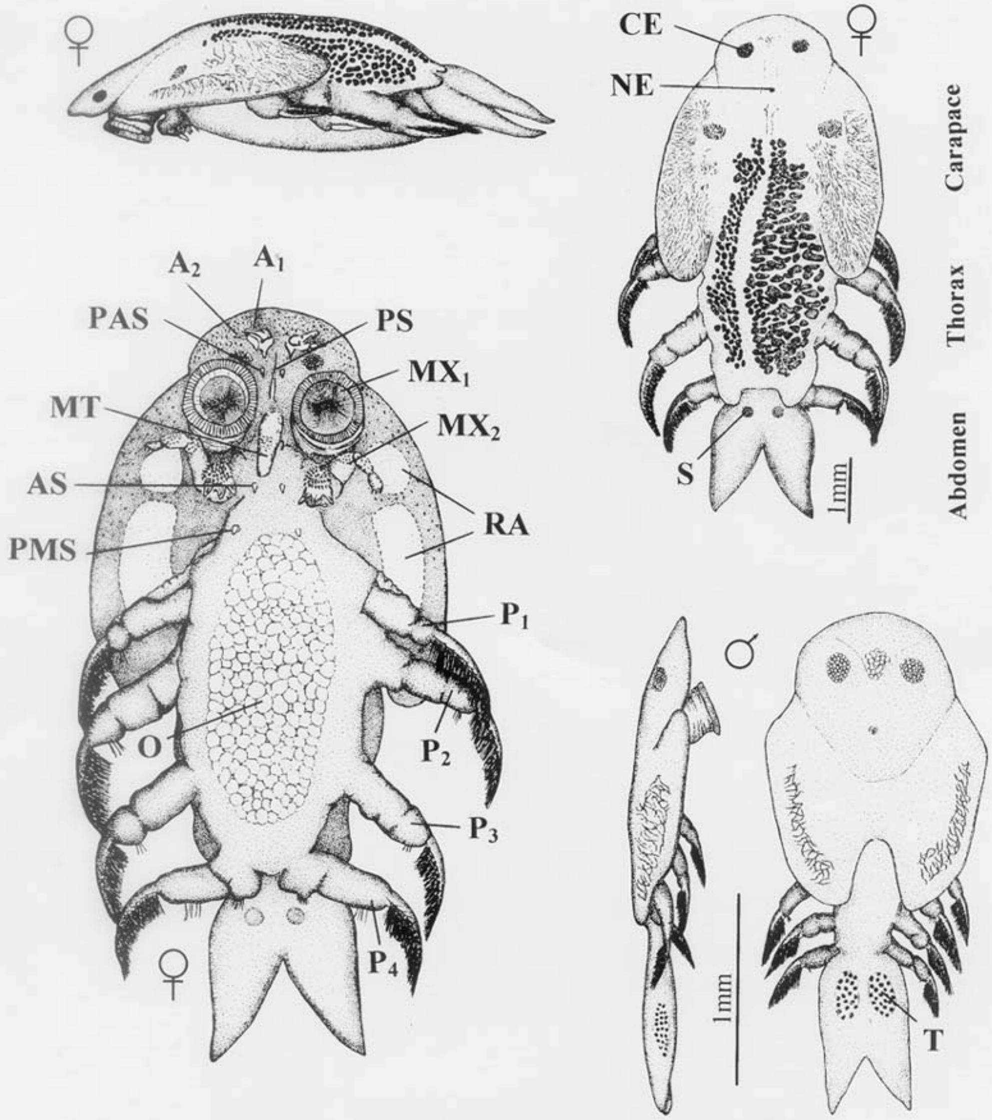


Figure 1. Example of general habitus of *Argulus* spp. (species depicted is *A. alosae*): Compound eye = CE; naupliar eyes = NE; first antenna = A_1; second antenna = A_2; postantennal spine = PAS; preoral stylet = PS; mouth tube = MT (note that the mandibles are too small to be seen within the mouth tube); first maxilla = MX_1; second maxilla = MX_2; accessory spine = AS; postmaxillary spine = PMS; thoracic legs 1-4 = P_1, P_2, P_3, P_4; respiratory areas = RA; testis = T; spermatheca = S; ova = O.

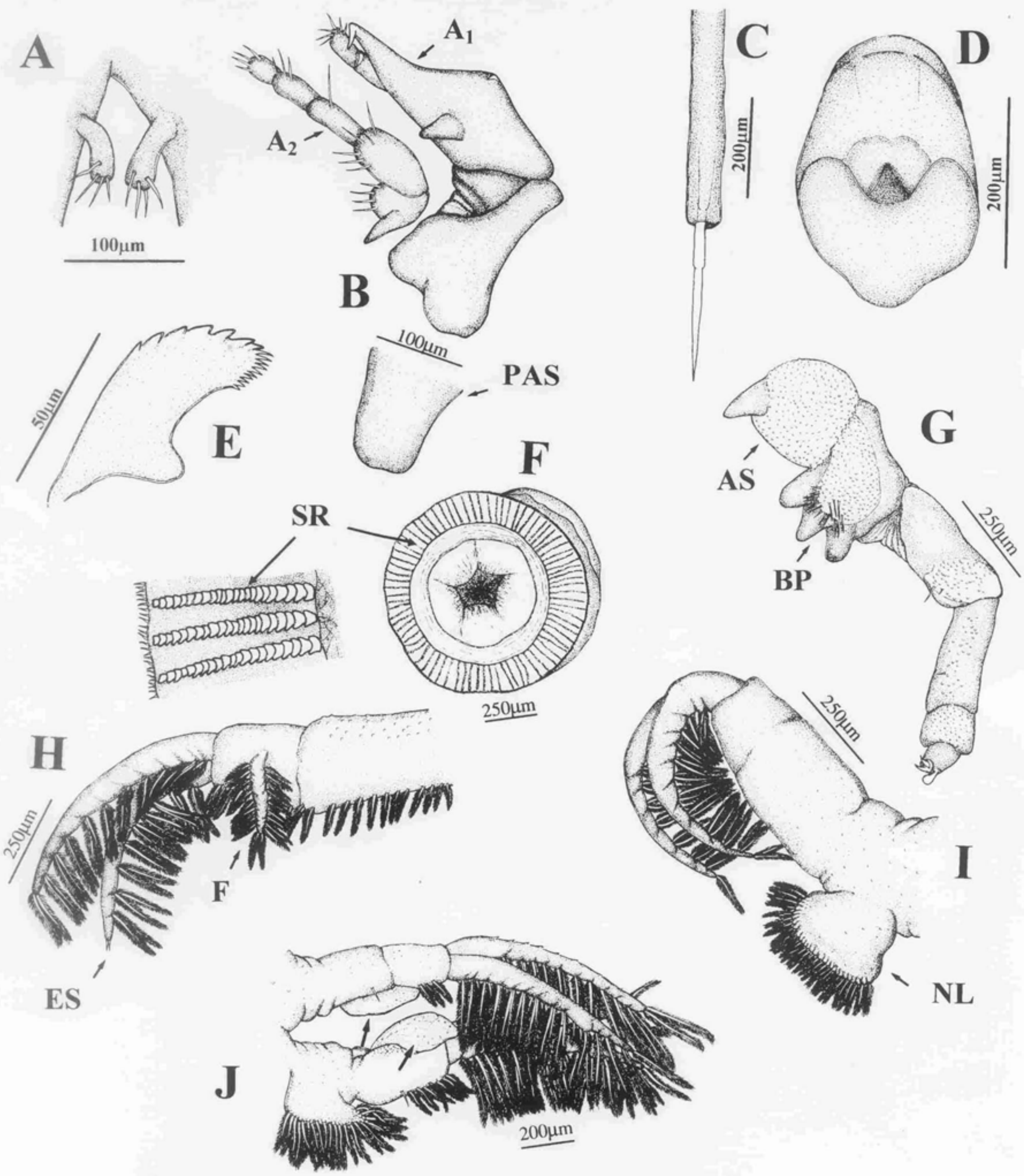


Figure 2A-J. Examples of general morphological structures of *Argulus* spp. (species depicted is *A. melanostictus*; unless noted otherwise illustrations depict female study material; most illustrations modified from Benz *et al.* (1995)): **A.** Caudal rami; **B.** Male first antenna (A_1), second antenna (A_2), and postantennal spine (PAS); **C.** Preoral stylet and sheath; **D.** Mouth tube; **E.** Mandible; **F.** First maxilla and close-up of several supporting rods (SR); **G.** Second maxilla (BP = basal plate of second maxilla) and accessory spine (AS); **H.** First leg (F = flagellum, ES = endopodal spines); **I.** Fourth leg (NL = natatory lobe); **J.** Male third and fourth legs showing modifications (arrows) associated with sexual dimorphism.

the base of the second maxilla (see Fig. 2G) there is an accessory spine (= first postmaxillary spine), and just posterior a postmaxillary spine (= second postmaxillary spine) (see Fig. 1).

The legs (= swimming legs, thoracic legs, thoracopods) are each cirriform and biramous, with two-segmented sympods (each composed of a coxa and basis), and rami each issuing two lateral rows of pinnate setae (Fig. 2H). The first two pairs of legs may or may not issue a flagellum (sometimes erroneously referred to as a flabellum) projecting from the basis and bearing two lateral rows of pinnate setae (Fig. 2H). The first leg typically issues two short apical spines from its endopod (Fig. 2H). Each leg may or may not issue setae along the posterior border of the coxa and basis, and legs often are ventrally armed with tiny scales or spinules. The fourth legs each bear a natatory lobe (= expanded portion of the coxa) issuing a row of pinnate setae along the posterior border (Fig. 2I).

Argulus species are dioecious, however, the sexes do not exhibit drastic morphological differences. Within a species, the adult female is usually larger than the male, and normally the male presents a thinner lateral profile (cf. male and female Fig. 1). The cephalic appendages may show some minor sexual differences, however, it is the legs of the male that are most notably different from those of a corresponding female. The sympods of the male legs often bear various protuberances and/or sockets (e.g., see Fig. 2J) which are used to help hold on to the female during copulation. The female bears spherical spermathecae in the anterior region of the abdomen (see female Fig. 1) while the male bears relatively larger elliptical testes in this same region (see male Fig. 1).

METHODS OF STUDYING *ARGULUS* SPECIMENS FOR IDENTIFICATION PURPOSES

General body form and fine details of the body surface and appendages are important in *Argulus* taxonomy, and examinations of these features are best carried out on fixed rather than living specimens. Prior to examination using light microscopy, specimens are normally fixed in 5-10 percent buffered formalin or 70 percent ethanol (ETOH). For long-term preservation, specimens are usually later transferred into 70 percent ETOH.

The general body form can be studied using low magnification microscopy with the specimen in a watch glass covered with 70 percent ETOH. The use of reflected light is normally employed when studying the general body form. To better reveal surface details some researchers lightly stain the surface of the specimen using lignin pink or chorazol black. These stains are applied by adding small amounts of them (in powdered form) to the ETOH bath which will contain the study specimen. Great care must be taken not to overstain the specimen, so prudent researchers usually sheperd the staining progress under a dissection microscope, ever ready to halt the progressive action of the stain by transferring the specimen into a fresh watch glass containing only 70 percent ETOH.

Because the respiratory areas are such important features in *Argulus* taxonomy, and because they are sometimes difficult to see, many researchers immediately search for these areas after viewing the general body form. Low power microscopy can be used to study the respiratory areas, and most agree that they are best seen using reflected light. To make the respiratory areas more evident, some advocate the use of various stains (e.g., lignin pink, chorazol black, or various hematoxylins). The use of phase contrast microscopy can also be effective in rendering the respiratory areas more visible. Sometimes the respiratory areas cannot be completely seen because one to several thoracic legs obscure them. In these instances it might be necessary to dissect the offending appendages from one side of the body (retaining them in serially labelled vials containing 70 percent ETOH for subsequent study).

Because fine details of the appendages are so critical in *Argulus* taxonomy, specimens must usually be dissected so that appendages may be manipulated and viewed at higher magnifications. Before dissection (but after study of the general body form and respiratory areas) specimens are often cleared using lactic acid or a solution of 10 percent KOH. A small amount of lignin pink or chorazol black added to lactic acid will both clear and stain the specimen. Clearing and staining is best accomplished in a watch glass so that the progress of these techniques can be assessed under low magnification, and once again, care must be taken not to overstain specimens. Dissections are accomplished in a watch glass under low magnification using fine insect pins embedded in

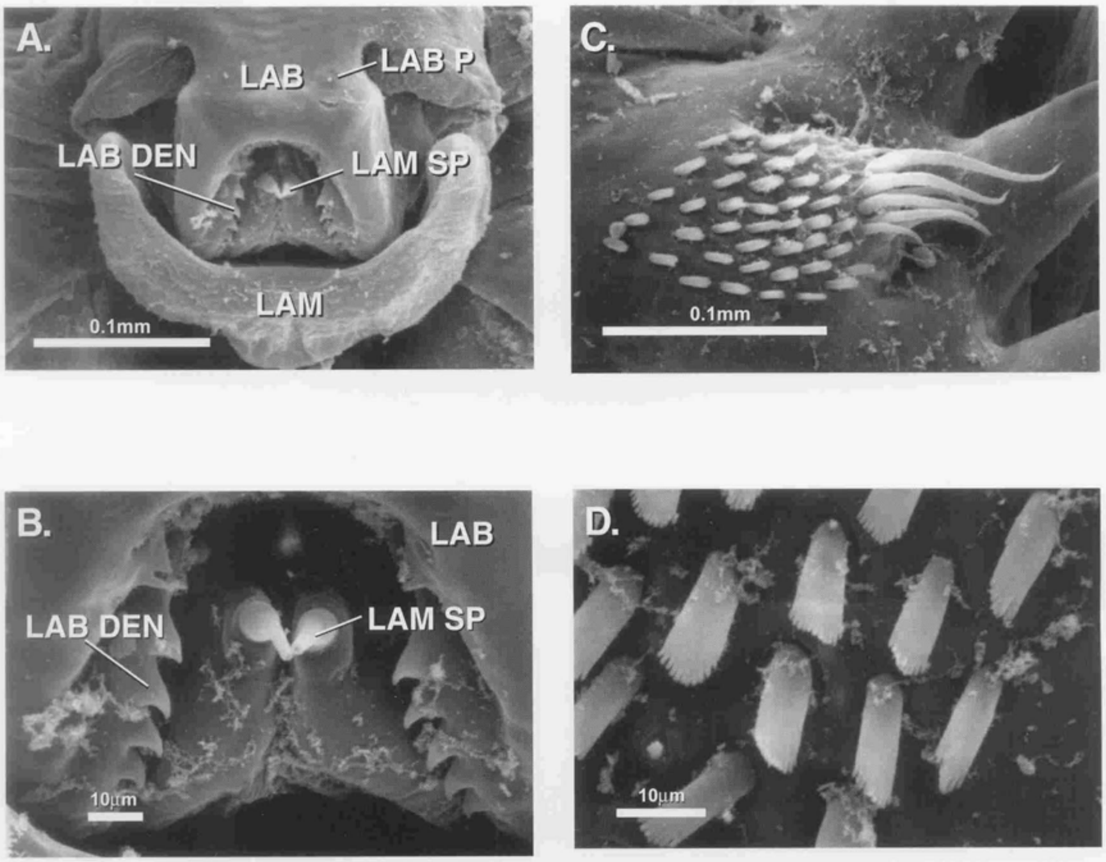
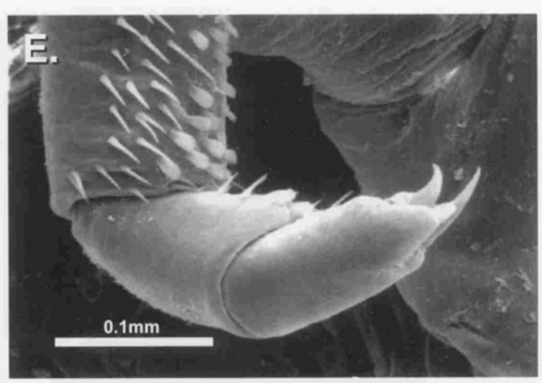


Figure 3A-E. Some features of *Argulus* sp. as seen using scanning electron microscopy: **A.** Tip of mouth tube. LAB = labrum, LAB DEN = labrum denticles, LAB P = labrum papilla, LAM SP = labium spine, LAM = labium; **B.** Opening of mouth tube. Abbreviations as in 3A; **C.** Central portion of basal plate of second maxilla (note two distinct types of cuticular armature as well as basal portions of 3 large basal plate tines); **D.** Close-up of pectinate armature elements of basal plate of second maxilla; **E.** Segments 3-5 of second maxilla.



the tips of thin wooden dowels. The tips of these pins may be filed sharp on a sharpening stone and used as tiny blades to carve off appendages for examination. Dissections are most safely carried out with the specimen submerged in a drop of lactic acid or a puddle of 70 percent ETOH so that detached appendages are not so likely to be flicked across the room by the sometimes whippy action of the dissection needles.

Once detached, appendages and other structures may be moved about or transferred to viewing slides using a fine hair artist's brush. The hanging drop technique of Humes and Gooding (1964) is very useful (see Fig. 4) for examining the fragile appendages under high magnification without the distortion created by coverslip pressure on fragile structures (a small drop of lactic acid serves well as a relatively viscous and nonvolatile suspension fluid). Dissected appendages can be viewed using bright field microscopy, however, the use of phase contrast microscopy can sometimes enhance viewing. Attempts should be made to examine dissected structures in several views (*i.e.*, dorsal, ventral, etc.) as surface ornamentation is usually not uniform. Once dissected, appendages and other structures may be stored in small stoppered insect vials filled with 70 percent ETOH, and these in turn may be protected in a larger sealed container filled with the same preservative. Naturally it is important to keep field records with specimens (date and locality of collection, host species, location on host, etc). It is also a good idea to accurately illustrate the study specimen so that comparisons to other specimens and the literature may be made without constant hovering over a microscope. The keen observation and thought involved in preparing accurate scientific illustrations also facilitates a thorough understanding of the morphology of observed specimens. Use of a camera lucida or drawing tube greatly facilitates accurate renderings of these complex parasites. Lastly, while some have attempted to use photomicrography to record the morphology of *Argulus* specimens, the results of this method typically fall far short of a proper illustration. This occurs because at higher magnification the specimen is thicker than the focal plane and hence portions of the image are rendered out of focus.

Over the past decade, high resolution images produced by scanning electron microscopy (SEM) have significantly extended our knowledge of genus *Argulus* (e.g., see Sutherland and Whittrock, 1986; Overstreet *et al*., 1992; Swanepoel and Avenant-

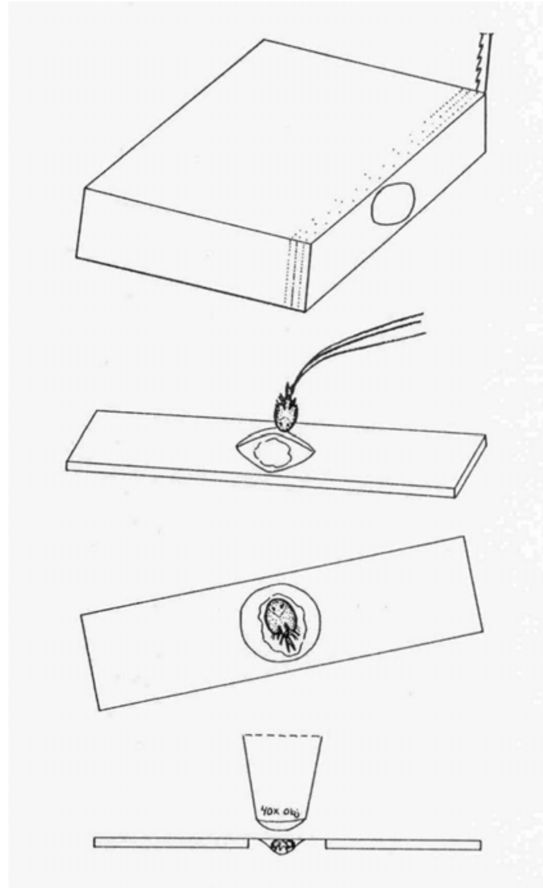


Figure 4. The hanging drop technique of Humes and Gooding (1964). Rectangular wooden slides are cut using a saw to match the dimensions of standard glass microscope slides (see top illustration). This is best done by first trimming a block of wood so that subsequent thin cross sections of it produce proper size slides. Prior to this cross sectioning, a hole should be drilled through the block so that subsequent cross sectioning will produce slides each with a hole in the center. The diameter of the hole should be slightly smaller than a circular microscope slide cover slip. Cover slips should be centered and glued over the holes of finish cut slides. To use these slides, a small drop of lactic acid is placed on the well side of the cover slip and the study material is added (see middle two illustrations). Next the cover slip is inverted so that the study material hangs suspended in the small drop, and the slide is mounted on the microscope stage (see bottom illustration).

Oldewage, 1992; Avenant-Oldewage and Swanepoel, 1993; Gresty *et al*., 1993). While this method of microscopy is not readily accessible to those outside research centers and universities, if more widely used SEM would greatly assist in taxonomic studies of fish lice by providing clear details of fine body structures (e.g., see Fig. 3A-E). Specimen preparation for SEM and techniques of SEM are beyond the bounds of this report, however, we refer interested readers to the methods sections in some of the papers cited locally above, and to reports by Pulsifer (1975) and Felgenhauer (1987).

Acknowledgments

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FISH CULTURE OF THE PIRARUCU

J. BARD AND E.P. IMBIRIBA

Translated from the original 1985 French article:
Pisciculture du pirarucu. La Pisciculture francaise, no. 81, pp. 29-33.
by Robert Streit for Jim Anderson of the Shedd Aquarium

Abstract: The pirarucu, **Arapaima gigas,** family Osteoglossidae, is the largest freshwater fish in the world. It is an equatorial warm-water fish living in the Amazon River Basin. Its diet is carnivorous, and it is an air-breathing fish. Its natural habitat is the "black" waters of the forest, in still areas. Breeding occurs during the rainy season. It is fished mainly with harpoons.

INTRODUCTION

Breeding in artificial waters is simple; however, sex separation is difficult, and the great size of the breeders is a complicating factor (they are over 40 kg). The pirarucu has been used successfully in extensive fish culture in reservoirs in northeastern Brazil. In intensive fish culture it is easily reared in fish ponds of any size. The yields at present vary from 1.7 to 11 metric tons per hectare per year, but better production may be hoped for. Fingerlings are collected in natural waters or reservoirs with the use of cast nets, in order to save breeder maintenance. Feeding involves using either small local fishes or small tilapia produced in waters rich in organic nutrients from cattle or buffalo-raising or any other inexpensive process. The average weight of an individual in intensive fish culture is between 5 and 10 kg or more, and fresh pirarucu tastes like fresh cod.

Since the efficiency of food chains is low, cultivation of carnivorous fish is seldom successful; still, because no rule is absolute, especially in tropical fish culture, exceptions may exist, and the fish culture of the pirarucu could well be one of them.

The pirarucu, *Arapaima gigas,* family Osteoglossidae, is the giant of the world's freshwater fishes. Specimens of 200-250 kg have been found. In truth, very few people, outside of a few illiterate fishermen, have seen them. The reason is that these large fish are caught most often in locations where there are no means of preserving them and no scales strong enough; estimates of weight are made by extrapolating from the dimensions of the fish's head or other bony parts. In contrast, "medium-sized" specimens weighing 50-90 kg are found at fishing sites, in the markets of the Amazon region, and...in the pools of public gardens, for the entertainment of visitors.

Curiously enough, scientific knowledge of the pirarucu has been acquired laboriously, and the folklore of the fishermen is full of legends as marvelous as they are fantastic. One had to wait for the masterful works of ESTAVAO de OLIVEIRA (1939), FONTENELE (1948), SANCHEZ (1972), and GUEVARA (1975) for reliable data on the biology, fishing, and other possibilities of this fish, although these data are far from complete. The work presented in this article represents a certain increment in the technical knowledge, but much remains to be done.

The name pirarucu means, in the language of the Amazonian Indians, "red fish," alluding to the red color of the posterior end of the scales which appears under certain conditions in the life of the fish, especially in the male. Since the fish culture of the pirarucu is based on numerous peculiarities of the anatomy and physiology of this fish as well as knowledge of its habitat, it is necessary to give a few details on these subjects.

Habitat

The pirarucu is a warm-water fish (24-31 degrees C) of the Amazon Basin. It is absent from the lower reaches of this river, probably because it does not tolerate the marine influence, and the limits of its habitat on the upper reaches of the Amazon and its tributaries are not known. It is absent from the basin of the Orinoco; it has been seen in former British Guyana and French Guiana, but in the latter the data are from the period prior to the agreement of 1897 which gave to Brazil the "contested territory" of Guiana and its current presence there is therefore doubtful. Its preferences tend toward the "black" water of the forest, in still waters; it is not found in areas with strong currents or in muddy waters.

Anatomy

The body of the fish is elongated and circular in cross-section, covered with enormous, very thick scales. The pectoral and ventral fins are very far apart. The dorsal fin and the anal fin are very close to the caudal fin, from which they are only slightly separated. The color is light auburn, darker in the young, and changes in the male at the time of reproduction.

The mouth is equipped with a bony tongue, a bony palatine plate and two bony lateral plates, the whole thing with rough surfaces which allow it to seize and restrain its prey; the digestive tract is short, as in all carnivorous fish.

The pirarucu has two respiratory apparatuses: gills for aquatic respiration and the air bladder, which connects with the digestive tract and serves the role of a lung.

The reproductive apparatus is very unusual. The female has only one ovary, the left; the right testicle of the male is likewise atrophied, only the left testicle being functional.

Physiology and Behavior

There are more curious features. The pirarucu feeds by literally sucking in its prey, which it crushes in its bony mouth. It appears to be rather eclectic in its choice of food, although information is missing on this point. Above all, it is the respiration that is very special for a fish; this is a **compulsory air-breather**. Adults come to the surface to breathe approximately every 20 minutes and the young more frequently. When a hatch remains in a group, i.e., in their earliest life stage as fingerlings, all of them breathe at the same time, creating the impression that the water is seething. If the pirarucu is prevented from coming to the surface to breathe, it dies, since the oxygenation provided by its gills, assuming it exists, is insufficient. It survives quite well out of water, a day or more, provided its scales do not dry out.

Growth of the pirarucu is very fast, although it is not very well known in its natural surroundings. A one-year-old fish weighs more than 10 kg, the females apparently growing faster than the males. The pirarucu generally swims in medium-depth water and rests from time to time on the bottom. If it is in danger, it can make spectacular leaps and not come up to breathe for 40 minutes. Often, without apparent reason, it leaps from the water and falls back on its side, making a loud beating noise.

During breeding, which takes place, with local variations, in the rainy season between October and July, the upper part of the male's head takes on a darker color, which extend to the beginning of the dorsal fin, while the sides, belly, and caudal region take on an attractive red color. The female remains a light auburn and it is only at this time that the sexes can be distinguished. The age of sexual maturity in the natural environment is not known; it must be between two and five years, depending on growth. What is certain is that breeders are very large specimens, weighing over 40 kg. There are several spawnings during the breeding season, since not all the female's ova are ripe at the same time. The spawning takes place in shallow water, less than a meter in depth. The male and female build the nest, which is approximately .20 m deep and .50 m in diameter or less, in the form of a spherical mound in a clayey bottom area without vegetation. The young stay in the nest for five days until resorption of the vitellus sac. In Brazil more than 11,000 young have been counted in a hatch. The young are protected by the parents and remain in a school for a long time, about two months. The number of spawnings per season for a single female is not known.

From these characteristics come the techniques of fishing and of the extensive cultivation of the pirarucu.

Fishing

Fishing for pirarucu is facilitated by the species's breathing and reproductive habits, which allow the fisherman to harpoon the fish as it surfaces to breathe or swims over its nest. Fishing with a hook is not easy, as the animal's mouth is too hard, and its size makes the use of nets costly. Whatever the type of fishing, the pirarucu is always caught dead by wounding or by drowning. As a result, it is very rarely commercialized fresh; the most common procedure is for the fisherman himself to salt the fish right at his fishing location. The fish is thus a substitute for salt cod, which is imported and , naturally, much more expensive. This is a very widespread trade in the principal towns of the Amazon. In view of the enormous extent of its range and the relatively concentrated nature of commercial fishing to supply urban centers, it is hard to get an idea of the status of stocks that could be overexploited locally. In any case, the minimum size of fish which may be kept has been fixed at 1.50 m; but enforcement is difficult to control for a fish that is rarely sold whole and whose places of capture are widely dispersed.

Extensive Fish Culture

Starting in 1939 ESTEVAO de OLIVERA was able to breed the pirarucu without difficulty in a pool at the zoological garden of the Belem museum. In 1942 nineteen specimens from that breeding were introduced by FONTENELE at the station of Lima Campos in the northeastern state of Ceara. At the age of three years, they measured an average of 1.20 m in length. Beginning in 1944 they were bred in fish culture pools of 150 sq. m, and the fingerlings placed in six reservoirs in northeastern Brazil that had been built to combat drought. Having verified that the pirarucu had bred in three of these reservoirs, starting in 1947 the responsible services authorized fishing for pirarucu with hooks in these three reservoirs. Success was immediate, for in two months of fishing, fishermen caught over 79 tons of pirarucu, some of which measured over two meters in length, and the official statistics are probably on the short side by default. Besides, it is difficult to believe that the approximately 1,000 fish this tonnage represents could have been caught by hook, given the hardness of the animal's mouth and the ease of fishing by harpoon or net in the reservoirs, where the pirarucu are much more easily approachable than in their native habitat; this would be underestimating the resourcefulness of the fishermen.

Since the fish culture post at Lima Campos has stopped producing pirarucu fingerlings, repopulation was not pursued, but the production of pirarucu was maintained into the 1970s. Since then, this species has disappeared from the production statistics of the National Department of Public Works against Drought. This is probably due to too great a use of nets; so the fishermen deprived themselves of a resource which was not negligible.

One can draw valuable information from this semi-success. First, if the pool-bred pirarucu did not reproduce until the age of five, those which were stocked in the reservoirs reproduced at three years and perhaps even earlier. One can find the reason in better growth: in the reservoirs three-year-old fish were over two meters long, at least some of them, while in the pool the breeders of Lima Campos did not exceed 1.70 m. Without doubt, the difference stems from the fact that in the reservoirs the pirarucu fed on live prey, while in the pool their food, though still suitable for carnivores, was much more heterogeneous.

Intensive Fish Culture

The implementation of intensive culture of the pirarucu proceeds from the considerable advantages offered by the species, but there are a number of difficulties which remain to be overcome.

The advantages are very great for this primitive, air-breathing fish: its incredibly fast growth rate, the quality of its meat with no intramuscular bones, which is as good as cod, and the ease with which it is filleted. The difficulties lie in distinguishing the sex of breeders, in their great size (over 40 kg), and in the animal's carnivorous diet.

The fist two difficulties are in practice rather easily overcome. For one thing, this particular kind of fish culture does not require many fingerlings--a maximum of 2,000 per hectare for a yield of 20 tons per hectare per year, and pirarucu fingerlings are very hardy and have an excellent survival rate, practically 100%. For production it is convenient to use a process that functions well for the African cousin of the pirarucu, *Heterotis niloticus:* collecting the fish together in their natural habitat or in a reservoir populated previously by pirarucu. Since the nests and the breeder pairs, as we mentioned earlier, are easily approachable, it suffices for the fisherman to follow the evolution of the spawning and collect the fingerlings by cast-net when they attain an average weight of about 100 g; the yield is good and in this way the fish farmer avoids all the annoying problems caused by separating the breeder pairs and by their appetite. The young pirarucu weighing 100 g eat small fish or freshwater shrimp; they are resistant to the fasting that their circumstances could impose, and they are not aggressive, nor is there any cannibalism. It is easy to transport them, since they come to the surface to breathe more frequently than adults. Some have indicated that the fish accept dead prey, such as fish cut into pieces; this is true, but live prey is always preferred.

The third difficulty, the one relating to the pirarucu's carnivorous diet, could be eliminated in several ways that vary with the ways in which they are raised. We should note first of all that in the native habitat of the pirarucu, i.e., the equatorial part of the Amazon basin, there are about 2,000 species of fish, of which a mere 10 species account for 93.2% by weight of the fish arriving at urban markets. This means that there are plenty of others to feed the pirarucu. One could also use the small tilapias that inhabit practically all the farm reservoirs not only of Brazil, but also of Peru. In fact, as the following examples will show, the intensity and productivity of the pirarucu culture depends on the intensity and productivity of the kinds of fish farming with which it is associated.

One need recall only the fish culture of the public and private gardens where the pirarucu, given a random diet of meat chicken, or waste fish, even pieces of bread, is maintained without growth and in reduced numbers.

The "pioneering" fish cultures of ESTEVAO de OLIVEIRA and FONTENELE were aimed only at breeding the pirarucu only in small ponds. These operations were successful, but neither growth nor commercial fish production were investigated. One had to wait until 1973 for the first attempt at growing the pirarucu in pools to be undertaken at the station at Iquitos (Peru). The fish used were fingerlings collected in their natural habitat, which received a diet consisting of rice bran mixed with the blood of slaughtered livestock. This food was eaten by the fish, but growth was very poor and the experiment had to be terminated...by buying market fish to feed to the pirarucu.

Much more interesting was the experiment performed by GUEVARA at the Tropical and High-Altitude Veterinary Institute of Pucallpa (Peru) in 1975. He raised young pirarucu which were already large--they weighed an average of 1 kg--in a pond with a "monk" to drain it and with a surface of 2,600 sq. m serving as a watering place for cattle. The pastureland above the pond received mineral phosphate fertilization. The period of fish farming was **one year**, after which the pond was drained. The following results were established:

Fish stocked: 40 pirarucu weighing on average 1 kg (source- Rio Ycayali)

Fish harvested: 40 pirarucu weighing on average 12 kg; min. 10 kg, max 16 kg

Total weight obtained: 480 kg

Net yield: 440 kg, or 1,692 kg per hectare per year

The yield comes from the mineral fertilization of the pasture, which flows as runoff into the pond and to which is added the organic fertilization provided by the cattle when they go to drink. This fertilization stimulated the production of the small planktonophagic and detrivorous fish that were already found in the pond (brought by the feeding stream and belonging to the families Characidae and Loricariidae), and these fish with no commercial value served as food for the pirarucu. This is an excellent way of utilizing cattle watering places in equatorial waters. The yield per hectare is not very high, but apart from payment of the fisherman who caught the "fingerlings," there are no production costs.

The authors of this article, working in Belem (Brazil) at the Center for Humid Tropical Research (CPATU) under the Brazilian Enterprise for Agronomic Research, began experiments in November 1984 to achieve more intensive net yields in pirarucu culture. Although the estuary zone of the Amazon and the Tocantins are outside the natural range of this fish, favorable conditions do exist at these locations:

- first, the presence of an abundant population of pirarucu in the artificial lake of Bolonha, which serves as a reserve of fresh water for the city of Belem; this has made capturing fingerlings a simple matter. (The pirarucu in this lake come from the garden of the Belem museum, and commercial fishing there is prohibited.)

- in addition, the existence, above the CPATU fish culture station, of cattle sheds with approximately 250 buffalo. The effluents from these cattle sheds pass into a small reservoir of 3,000 sq. m which cannot be drained and in which the herd bathes, furthermore, every day. The waters of the reservoir, as fertile as they are turbid, support an abundant population of *Tilapia nilotica,* as well as several local fishes (mainly Loricariidae and Callichthyidae). Since the tilapia population cannot be controlled, as there is no periodic emptying of the reservoir, there is an overpopulation and nanism.

The pirarucu are raised in earth-enclosed pools of 20 x 5 m, i.e., 100 sq. m, fed by the water of the above-mentioned reservoir and capable of draining by rocker pipe.

Four fish farming groups were established with densities of 6, 11, 15, & 20 pirarucu fingerlings per pool; the fingerlings are fish weighing approximately 100g on average, except for the first group of 6 pirarucu, which was established with fish weighing 388g.

The diet consists of small live tilapia caught in the reservoir either with a cast-net or with a small seine. The rations are evaluated fairly roughly with a bucket holding 8 kg of tilapia and calculated according to the approximate daily weight gain of the pirarucu, taking into account a transformation coefficient of about 7. In fact, since the tilapia resources were very abundant and the presence of manpower rather irregular, one made sure especially that there was always a supply of food in the pools. Since the water was turbid, it was impossible to monitor directly that the prey was eaten. The following table gives the results for the first two groups, those of 6 and 11 pirarucu, in average individual weight, with calculation of daily weight gain by each specimen and in relation to the unit of surface area (hectare).

Individual Weights of Pirarucu (in grams)

Month	6 Pirarucu	11 Pirarucu
11/84	388	126
12/84	1,500	405
01/85	2,300	1,251
02/85	3,125	1,730
03/85	3,460	2,420
04/85	4,497	4,037

	6 Pirarucu	11 Pirarucu
indiv. growth, g/day	27.4	26.07
growth per ha, kg/day	16.4	28.6

Results for the other groups will be known or evaluated starting in August 1985.

It's likely that those results will be even better, for, as has been stated, the pirarucu is a peaceful animal, and the fish do not fight with each other except during the time of reproduction. The aim of the experiments will be to determine the maximum possible population density as well as the best weight for commercialization. In practice one will have to give much consideration to the risk of theft, although in this respect the turbidity of the waters is more of a favorable factor for the Belem station, since the fish are never visible when the pools are full.

The costs of production are evidently higher than for the GUEVARA's Peruvian experiment, since they include amortization of the costs of constructuring the ponds, the manpower for catching the pirarucu fingerlings and the tilapia that serve as their food; but the pools are of a simple kind, a half-day of fishing is enough to collect 1,000 fingerlings or more, and, under the conditions of the Belem experiment, and hour of fishing by cast-net produces 10 kg of tilapia. In addition, the pirarucu got a superabundance of food; when the pool containing six 5-kg pirarucu was emptied in April 1985 it was found to contain over 40 kg of tilapia which themselves had been reproducing.

It is too early to draw conclusions, but for now one could say that starting with fish, or, more precisely, fingerlings weighing 100 g, at 5 months one has fish weighing 4 kg and at 6 months fish weighing 5 kg, with a **minimum** population density of 11 fish per 100 sq. m, i.e., 1,100 fish per hectare or 5.5 tons of fish per hectare in 6 months, and this figure could easily be doubled. Naturally, the surface area of the ponds is important to the pirarucu, and in all cases it is advantageous to raise the feeder fish and the pirarucu simultaneously and in the same pond, as GUEVARA did. This is how they would have proceeded at Belem if the reservoir holding the tilapia had been equipped with a draining apparatus, but such was not the case.

For now, one should remember from this experiment that in the equatorial zone, whenever cow, buffalo, pigs, or poultry are raised, and the topography is suitable, there can be an associated intensive fish culture of pirarucu. It is difficult to say whether the tilapia is an indispensable intermediary, because it is impossible to compare GUEVARA's experiment, which involved raising cattle **in pasture**, to the experiments in Belem, which were associated with raising buffalo **in stalls**. But neither the Brazilian nor the Peruvian farmers will ask themselves this question, since tilapia are present in practically all the reservoirs on their farms (without, incidentally, any ill effects for the native wild fauna).

A question that could in fact be asked is whether it makes more sense to directly produce selected all-male tilapia, or pirarucu with tilapia as an intermediary. This study remains to be tried in the field.

In the meantime, the Belem station has undertaken experiments in producing *Tilapia nilotica* controlled by pirarucu--5, 10, or 15 pirarucu per 100 tilapia--which will produce some rather unexpected results.

Elsewhere, it has been noted that the pirarucu has frequented the irrigation canals of the "Jari" project's rice plantations in the Amapa territory north of the Amazon estuary and has even begun to breed there. Since the rice byproducts are locally abundant, it has been proposed that the reaches of the canals between the locks be isolated by means of grills and that pirarucu be raised there as rice bran is dumped in the water to attract feeder fish.

Possibilities for Pirarucu Fish Culture in French Guiana

If the pirarucu does not exist or no longer exists in Guiana, it is not difficult to obtain them in Belem (1 hour, 40 minutes by plane, two connections per week), but this introduction would not be valuable for intensive fish culture until there were farms disposing of organic waste in sufficient quantities...and this may already be the case.

For extensive fish culture the pirarucu would certainly be very useful in the future Sinnamary River reservoir to balance the fauna there and provide an attractive resource for any fishermen.

Finally, there are functioning rice-growing projects near Saint-Laurent-du-Maroni. Could the pirarucu have its place in the canals?

All of this is fairly embryonic, but equatorial fish culture and particularly that of the pirarucu are certainly worth some attention in view of their enormous potential. Didn't France's trade balance in the fishing industry show a 4.1 billion-franc deficit in 1984?

Submittors Note:

This article was translated from French at the request of Jim Anderson, Shedd Aquarium. Although it does not provide the definitive word on Arapaima propagation (as hoped), it does present some interesting insights into natural history. The full citations of the references were not provided in the original article. Also, the quotation marks surrounding several words and phrases and the ellipses all appeared in the original text. They do not represent imprecise translation nor omitted words. Finally, "monk" on page 4 is a curious usage. The original text was avec "moine" de vidange. Does anybody have an idea as to how they drained the ponds?

Please refer to the original if citing this article as a reference. The authors should be contacted regarding requests for reproduction. Previously, Jim has addressed correspondence to: Federation Nationale des Pisciculteurs-Salmoniculteurs de France 11 rue Milton 75009 Paris, France.

AQUARIUMS IN CHINA

David Hardley
Systems Design

Marinescape Ltd

Marinescape is just about to start construction on another Aquarium in China, location Beijing. For those not in the know Marinescape has been involved in large Public Aquarium construction for the last ten years. Through the experience of these years the Aquarium design has evolved from the first of its type, Kelly Tarltons Underwater World, Auckland, New Zealand to the present. Kelly Tarltons Underwater World incorporated a 90 metre long acrylic tunnel section with a moving walkway and large gravity fed sand filters taken straight from waste water treatment technology. This Aquarium led to other large Aquariums designed on similar principles these include Manly Underwater World Sydney, Australia; Perth Underwater World, Australia; Darwin Aquarium, N.T., Australia; Mooloolaba Underwater World, Brisbane, Australia; Sentosa Underwater World, Singapore; Ocean Park Shark Tank, Hong Kong; private Aquarium for Sultan of Brunei; Deep Sea World, Edinburgh, Scotland Sun Asia Ocean World, Dalian, China, and now working on a Aquarium in Beijing.

The Aquarium in Beijing will follow the same basic design of the last two projects which is a large main tank 50 metres by 25 metres with water depth 3.2 metres high (approximate water volume 4 million litres, I million US gallons), acrylic tunnel length over 100 metres and large gravity sand filters as the main filtration device. Incorporated is a large exhibition floor containing twenty small tank displays ranging in size from 200 litres to 8000 litres and three rockpools ranging from 10000 litres to 100000 litres.

The Beijing project will be a completely closed system which offers Marinescape some exciting challenges. As in our basic recipe we believe and rely on the use of large gravity sand filters as these have proven very successful in our aquarium design concepts. But we are also including many other features such as Ozone, U.V., Foam Fractionation devices and hopefully some form of Denitrification system. All these system are used by some degree in other aquarium systems with advantages and disadvantages.

Our aim is to incorporate all of the above systems with our basic recipe to form a Homogenized system that is cost effective and efficient to run which maintains good water quality and specimen health. Construction is due to start in November 1995, scheduled completion of the project December 1996. An interesting feature of the Aquarium is that it will be built under an 8 million litre fresh water pond.

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NEW MONSANTO ECO-CENTER
OPENS AT SPRINGFIELD SCIENCE MUSEUM

SPRINGFIELD, Mass. - The Monsanto Eco-Center, a new aquarium and live animal center, has opened at the Springfield Science Museum in Springfield, Massachusetts.

Designed with realistic habitats, life-like vegetation, and moving water, the Monsanto Eco-Center features some very unusual creatures -- fish that walk on land, turtles that look live leaves, and frogs which produce poison.

The state-of-the-art aquarium and live animal center replaces the museum's original aquarium which opened in 1937. The new facility continues the Science Museum's long tradition of caring for and exhibiting live animals, especially fishes, reptiles and amphibians, in order to provide information about the environment and the importance of preserving natural habitats.

The center has been made possible with a grant from the Monsanto Fund, the philanthropic arm of Monsanto Company. Exhibits in the Monsanto Eco-Center were made possible entirely by gifts from private individuals, businesses and foundations.

The Science Museum is located at the Quadrangle on the corner of State and Chestnut Streets in downtown Springfield, Massachusetts. Hours are Wednesday-Sunday, noon-4:00 p.m. Admission is $4 for adults, $1 for children 6-18, free for children under six. The single admission fee provides entry to all four museums at the Quadrangle.

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FOR IMMEDIATE RELEASE