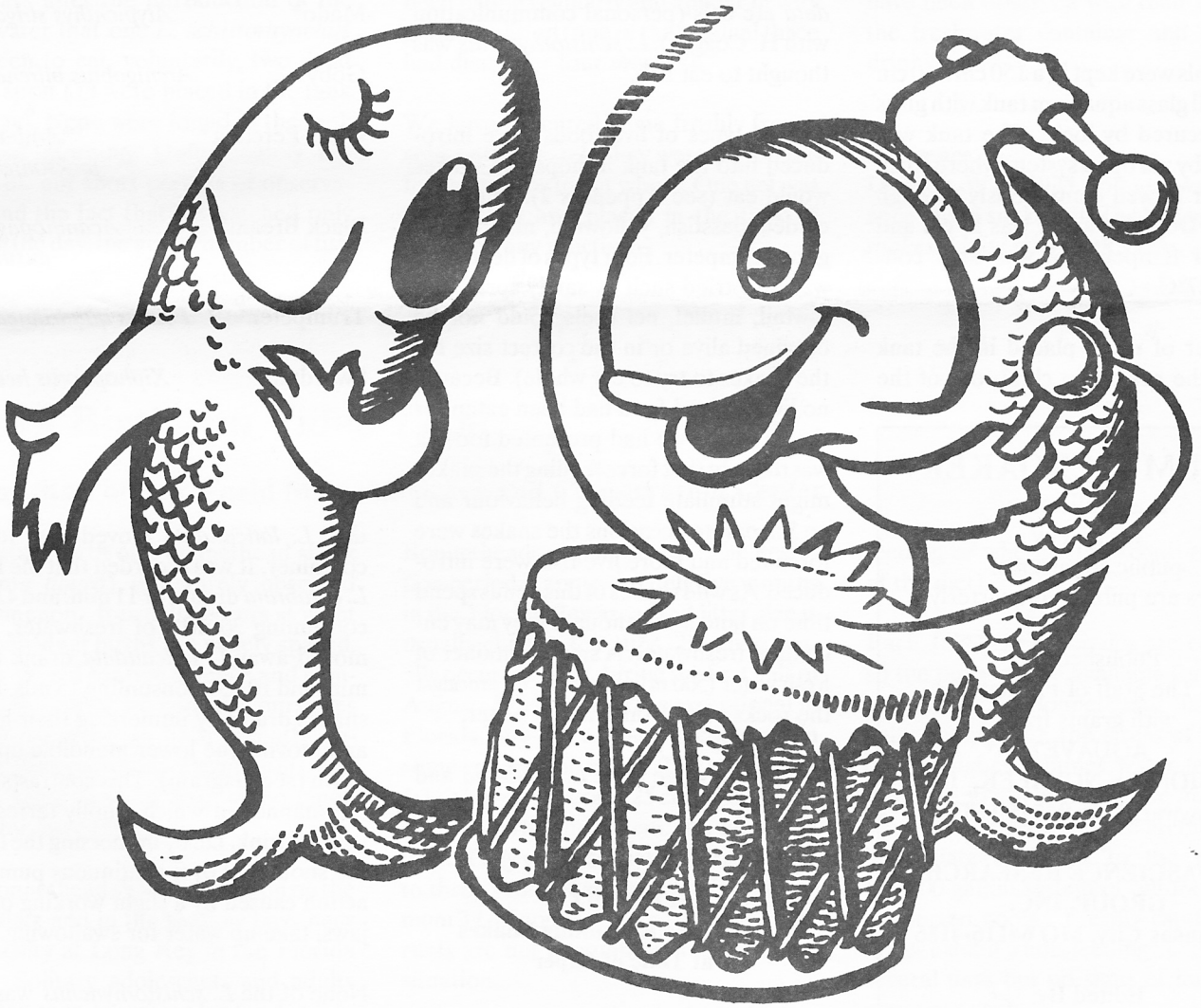
DRUM & CROAKER



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Observation of Sea Snakes in Captivity - (Genus *Laticauda*)

by J. West, Section Head Keeper, Aquarium and T. Boylan, Section Head Keeper, Reptiles, Taronga Zoo, Mosman, 2088, New South Wales, Australia

Taronga Zoo Aquarium received several specimens of the three species of banded sea snakes from Dr. H. Cogger and Dr. G. Megden of the Australian Museum. This article is of the observations of a group of snakes in captivity over a six month period.

The group of snakes concerned consisted of one *Laticauda laticaudata*, four *L. colubrina*, two *L. schistorhynchus* (see Appendix 1 for sizes of snakes). Over the observation period one of each species died.

All animals were kept in a 150 cm x 60 cm x 60 cm all glass aquarium tank with glass covers secured by locks. The tank was supplied by ;an open system where fresh salt water flowed continuously through the tank. Depth of water was 17 cm and the water temperature was kept constant at 27°C.

A number of rocks placed in the tank allowed the snakes to climb out of the water onto dry land. This is the only genus of sea snake that is not completely aquatic. Light was supplied by 2 x 100 watt spot lights for 10 hours per day and as the tank was sealed to prevent escape, air had to be supplied by a compressor.

The behaviour of these species of sea snakes is poorly known and there was little information available on their feeding habits. It was known they needed dry land to move around on and lay their eggs and that *L. colubrina* and *L. laticaudata* ate eels (personal communication with H. Cogger). *L. schistorhynchus* was thought to eat fish.

Several types of live foods were introduced into the tank in hope the snakes would eat (see Appendix 2). These included glassfish, yellowtail, mado, sand goby, trumpeter. Four types of dead food was also tried such as sandy sprat, yellowtail, mullet, eel (eels could not be obtained alive or in the correct size for the snakes to try to eat whole). Because no live or dead food had been eaten for the 10 weeks we had presented food, it was thought that force feeding the snakes might stimulate feeding behaviour and on 3 separate occasions the snakes were force fed and more live fish were introduced. As wild snakes of this genus spend time on land it was thought they may encounter freshwater. A small container of fresh water (500 mLs) was placed amongst the rocks away from the salt water.

Immediately one large *L. colubrina* and the *L. laticaudata* moved over to the container. It was recorded that the large *L. colubrina* drank for 11 min. and 42 sec. consuming 30 mLs of freshwater, as it moved away *L. laticaudata* drank for 4 min. and 10 sec. consuming 15 mls. Both snakes drank by immersing their heads and moving the lower mandible up and down (see diagram). This contrasts with the manner in which wholly terrestrial snakes drink, i.e. by immersing the tip of the snout and by a continuous pumping action caused by a slight working of the jaws, take up water for swallowing.

None of the *L. schistorhynchus* was observed to drink that day but may have drunk during the night. Only *Laticauda* species of sea snakes have been recorded drinking fresh water as most species, most likely, obtain their requirements from the fish they eat (Dawson).

APPENDIX 1
Size of Five Remaining Snakes at Time of Paper

Laticauda colubrina	125 cm
	80 cm
	75 cm
Laticauda laticaudata	60 cm
Laticauda schistorhynchus	81 cm
	80 cm

APPENDIX 2
Food Fish Offered to Laticauda SP
(* Live)

Sandy Sprat	*Hyperlophus vittatus*
Mullet	*Myxus elongatus*
Yellowtail*	*Trachurus novaezelandiae*
Eel	*Anguilla australia*
Mado*	*Atypichthys strigatus*
Goby*	*Arenigobius bifrenatus*
Glass Perchlet*	*Ambassis jacksoniensis*
Black Bream*	*Acanthopagrus australis*
Trumpeter*	*Pelates quadrilineatus*
Swordtail*	*Xiphophorus helleri*

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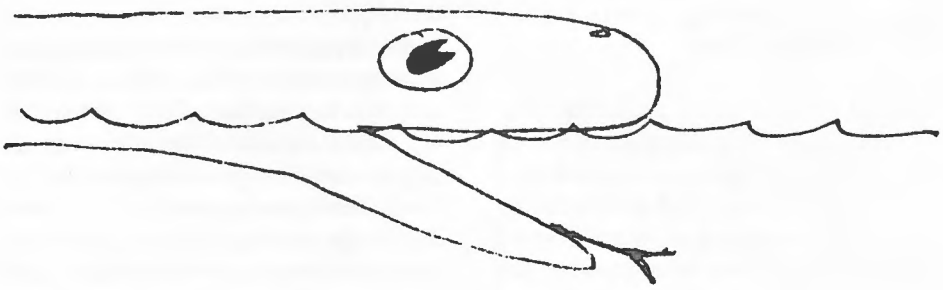


Drink Position of a Sea Snake

At this point live and dead fish were still being offered on a daily basis and it was two days after the introduction of the freshwater that one *L. schistorhynchus* was seen to eat, voluntarily, two dead sandy sprat (13 were placed in the tank that day). None were found in the tank the next morning. Unfortunately because of our short periods of observation and the fact that we watched only during the day, the actual number of fish any specimen has eaten is unknown. Since that time two *L. schistorhynchus* have been eating regularly and appear in very good condition (one of the original three had died after four months).

We have procured some freshly frozen eels, unfortunately they were all too big for the snakes to eat whole. One eel was thawed out and placed in the tank to check on any reaction from the snakes.

The large *L. colubrina* and *L. laticaudata* both bit the eel (*L. laticaudata* on four occasions) and both tried to manoeuvre towards the head of the eel. The eel was too big to eat, but this was a very encouraging sign. Unfortunately they have not accepted strips of eel and have been force fed with eel pieces on two occasions.

L. laticaudata has been observed on several occasions completely coiled up and submerged in the freshwater container for up to three days (once just before sloughing). All snakes at one time or another have been observed with their heads in the freshwater container and possibly drinking.

Reference

Dawson, W.A. 1975. Salt and water balance in sea snakes. In *The biology of sea snakes,* University Park Press.

Shark Births on Video Tape

by The Staff of Sea World Marine Science and Conservation Center

The actual birth of a bonnethead shark (*Sphyrna tiburo*) is a rarely observed phenomenon. It usually occurs at night and individual births are widely spaced. At Sea World Marine Science and Conservation Center we consider ourselves doubly fortunate to have recently observed numerous bonnethead births, and at the same time to have video-taped them for later review.

The bonnethead shark is common on the grass flats and in the shallow bays near our facility at Long Key in the Florida Keys. Solitary adolescents and adults are often seen searching for food in 0.5-2 meter depths, and occasionally during the winter months congregations of as many as fifty adults are seen in small bays of 2-4 meter depth where no concentration of food is apparent.

Bonnetheads pup annually. The gestation period is approximately five months in the Florida Bay area, and litter size is usually eight to ten pups. Pupping usually occurs at night during the first half of August. Infertile eggs are exceptional in Florida Bay but are not uncommon in some geographic areas. The sex ratio is 1:1. The pups average 25 cm. total length (TL) at birth and 60 cm. TL after one year. They reach sexual maturity at two to three years of age and attain a maximum TL of approximately 100 cm.; though runts are not uncommon in the captive situation.

The stomach contents of free ranging bonnetheads reveal a diet of cephalopods and crustaceans with a healthy percentage of seagrasses. (We are not certain if grasses are ingested incidental to feeding or whether they constitute part of the diet).

Each July gravid females are collected so the pups will be available for display and research. Bonnetheads have difficulty coping with the stress of capture during higher summer water temperatures (+30°C) however, we minimize stress with speedy capture methods and immediate transport to the facility's 500,000 gallon system of outdoor interconnected pools. Freshly captured females exhibit a non-feeding behavior for several days but no signs of long term stress are seen.

1985 was a typical year for our husbandry efforts. Water temperatures in the Bay and our facility fluctuated near 30 °C. Ten gravid females had been

collected in late July and by the 16th of August eight females had produced approximately sixty pups. At 1:30 p.m. on the 16th it was noted that one of the females was slightly more active than the other. The difference was quite subtle but closer observation revealed an umbilical cord trailing from the birth canal of the more active female and an obviously newborn pup was found in the pupping area.

Thirty minutes after this discovery the tip of a caudal fin could be seen at the birth canal of this female. At 2:30 p.m. the female was transferred by net to a nearby 15,000 gallon observation tank and at that time two half exposed caudals could be clearly seen at the birth canal. By 3:00 p.m. the entire caudal fins were exposed, and it was observed that while one fin was right side up, the other was upside down. At 3:30 p.m. during a two-minute lapse in observation, two pups were born and a clear, lightly tinted, tube-shaped tissue (the remnants of the egg case) had been expelled. More umbilical cords could be seen trailing from the birth canal.

By 3:45 p.m. another caudal fin was half exposed. By 4:15 p.m. this caudal fin was entirely exposed. Nothing unusual occurred for the next hour and fifteen minutes except that the caudal appeared to make occasional independent motions.

During her entire stay in the observation tank the female swam easily back and forth between the end walls, swimming up at each end to near surface then turning and swimming near the bottom to the other wall. Because of the long time interval between births we assume the pups are scattered widely during the normal birthing process. (We have never observed a concentration of pups in the wild).

This relaxed swimming continued until approximately 5:30 p.m. when a few moments of agitated swimming were followed by very agitated, erratic swimming, and the immediate birth of a fourth pup. Actual pupping occurred in a matter of 2 to 3 seconds. Pupping was followed in a few minutes by the half emergence of two more caudals; again, one was upside down.

By 6:20 p.m. these two caudal fins were nearly completely exposed when normal swimming was again interrupted by a few moments of agitated swimming followed by very rapid movement and a fifth pup. Within two minutes a sixth pup was born, again after the same unusual swimming. Immediately after the sixth birth two more caudals were partly exposed and within the next ten to fifteen minutes the last three pups were born. Video tapes reveal that at least one pup was upside down at the moment of birth.

At least two of the egg case remnants remained in the water column after pupping. They were probably not expelled at the moment of birth but the exact timing could not be ascertained. The placenta and umbilical cords were expelled intact overnight.

The pups were born with very light grey dorsal coloration except for the head area which was pinkish-grey and slightly translucent. Ventral areas were nearly white. At birth the dorsal fin was flaccid and curved backwards approximately one half its height. Within 24 hours it had attained its normal height and stabilizing action. The pectoral fins were immediately used for guidance. The head appeared laterally curved upward at the edges at birth, but within a day it became quite flat. The head became opaque after about a week. At birth swimming was coordinated but the pups appeared disoriented and swimming occasionally stopped. Within an hour after birth swimming was more routine and was not interrupted, however some initial swimming was done at the surface with a large portion of the head exposed. In previous seasons a few of the pups continued this activity sporadically for several weeks.

This litter was typical of years past. The pups show no feeding interest for the first two or three days of life. They swim constantly, as do the adults, and are easily frightened by underwater noises and by any encounter with an object. They are quite responsive to sounds but do not appear visually stimulated unless the object is very close. When feeding begins it appears to be more stimulated by olfaction than vision. In our captive situation the feeding efforts of one pup apparently stimulates the others and all begin swimming vigorously searching for food. Newborns exposed to direct sunlight begin tanning and take on a charcoal gray dorsal coloration with a light ring around the eye. This tan is temporary and does not occur under artificial light.

Bonnethead husbandry has proven to be uncomplicated. A few losses occur from premature births induced by capture, and with predation and the other usual problems associated with a captive environment about a 10% mortality is experienced during the first year. Unexplained losses are rare.

Filtered Bay water is pumped through our system of ponds during thewarm water months (April-December) and is recirculated and heated to 20°C during the winter, but an entirely closed aquarium system has proven adequate for bonnethead maintenance. We feed both pups and adults squid, capelin and shrimp once a day to satiation.

Density does not appear to be a problem. We routinely maintain as many as 100 pups in a pool 10m x 4m x 1m. We have maintained four pups in a 2m diameter circular tank for three months with no signs of stress. In fact, on one occasion a visiting researcher accidentally left ten pups overnight in a 3m x 1m x 0.5m enclosure at the facility. When found, the pups appeared no worse off for the experience. Light colored tanks walls should be avoided as they are poorly perceived by bonnetheads.

Although parasites are a major problem with many sharks we have seen no parasitic infestations of bonnetheads in, or out of captivity.

As display animals bonnetheads are a compact version of the hammerhead. They are active and hearty. As research animals they are plentiful, ship well, are easy to maintain, and can be observed

from birth to maturity.

We would like to thank Glenn R. Parsons of the University of South Florida whose study of the bonnethead shark has provided much of the data included here.

Submission for the next issue of Drum & Croaker (VOL. 22, No. 2) must be received no later than September 1, 1989.

Manuscripts may be submitted electronically (the preferred method) via EasyPlex, electronic mail on CompuService (address to: "FISHNET, 76703,4256"); by mail (to: FISHNET, 102 Hiram Street, Sheffield, AL 35660); or by FAX (to: 205-767-7484).

Telephone inquiries about Drum & Croaker articles or access to CompuServe (and FISHNET) to: John Benn, 205-381-4945 or John Kuhns, 816-842-5936.

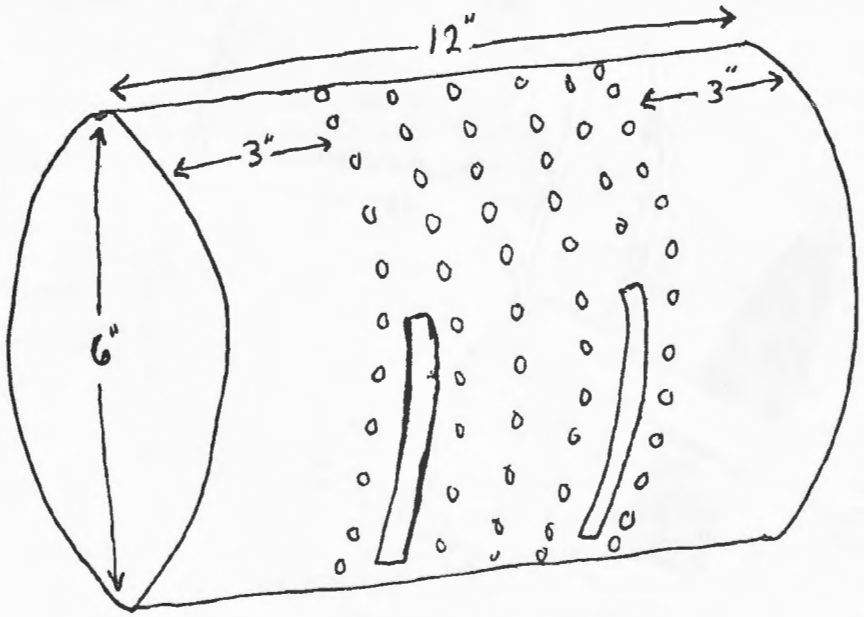
Practical Ideas for Constructing and Organizing Fish Collecting Gear

by William Gibbs and Donald Chittick, Sea World Shark Institute, Sea World of Florida, P.O. Box 968, Long Key, FL 33001

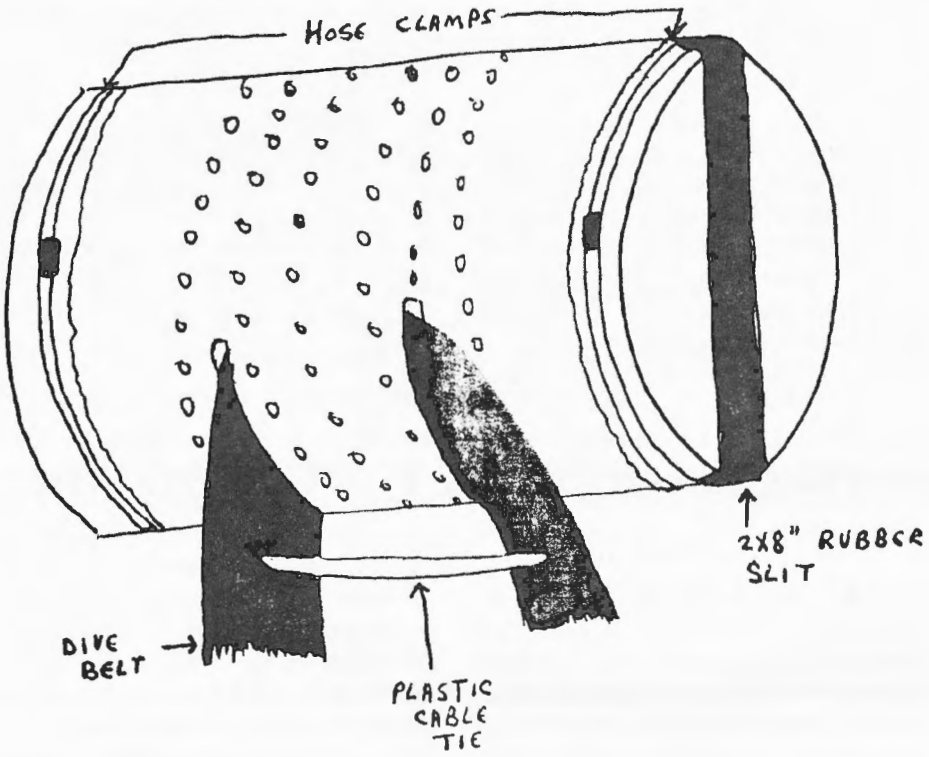
Scuba divers who collect marine tropical fish tend to lose efficiency and productivity trying to hold on to all the necessary equipment; fish container, hand net, drop net, probe, and quinaldine bottle, while swimming in a strong current.

Unless the diver keeps a good grip on his fish container (monopolizing one hand), the container can easily be swept away. An inexpensive collecting container can easily be constructed to hold fish and yet not be a burden to the diver.

The following instructions are for the assembly of an all purpose dive belt carrier. Collect together a twelve inch (30cm) section of six inch (15cm) diameter PVC pipe, neoprene rubber from an old wet suit (preferred material) or rubber tire innertube, two to four hose clamps, a six inch (15cm) elastic cord, two plastic cable ties, and a swivel eye snap. Measure three inches (7.5cm) in from the top and bottom of the PVC pipe then drill numerous quarter inch holes spaced all around in the remaining middle six inches (15cm). Cut two parallel slits in a quarter inch (.6cm) wide and long enough to fit a dive belt approximately four inches (10cm) from each end of the PVC pipe (see figure 1). Next cut two circles of rubber eight inches (20cm) in diameter. Stretch one circle over the bottom of the PVC pipe, securing the rubber with one hose clamp or two hose clamps united if necessary. Cut the second rubber circle in half and line up the halves over the top of the container with the two halves meeting but not overlapping. Cut a two by eight inch rubber strip placing it over the resulting slit and again secure with hose clamps. The dive belt is strung through the parallel slits and fastened around the waist, positioning the container over the left hip if you are right handed. To prevent the container from slipping make a hole in the dive belt next to the container and string a large plastic cable tie through the two holes (see figure 2).



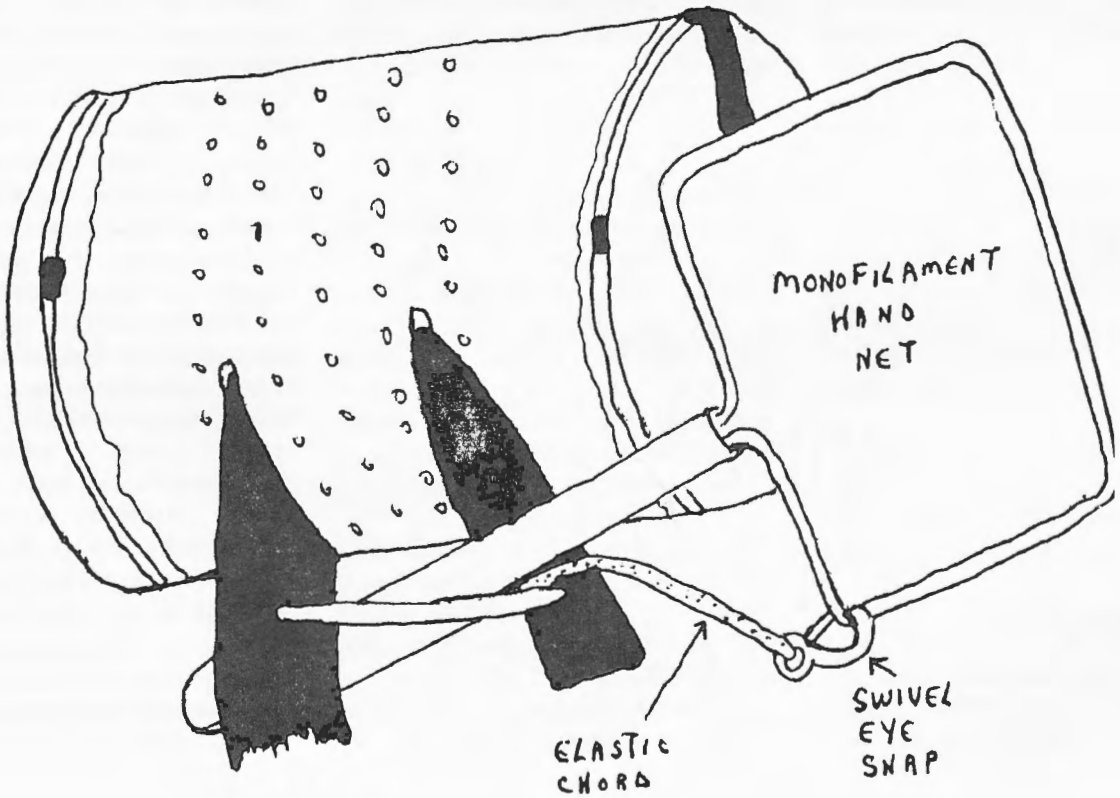
Specimens can be placed in the con-

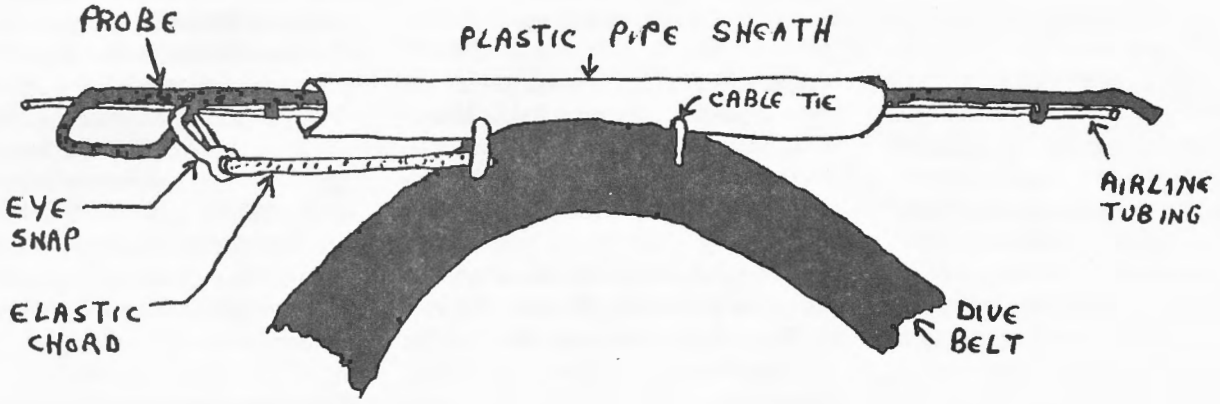


tainer easily through the slit on top, yet the two inch rubber strip prevents the fish from escaping. When the container is removed from the water the fish remain swimming in the three inches of water at the bottom of the container. A hand net can be carried between the belt and the container until needed. To prevent losing the monofilament hand net connect a six inch elastic chord to the belt and connect it to a swivel eye snap which holds fast to the net frame (see figure 3).

In addition, the right side of the dive belt can also be used to carry another necessary collecting tool, the probe. One should bend a twenty-four inch metal rod (one-eighth inch diameter stainless steel rod is best) to form a handle on one end and a slight bend at the other end. In order to remove fish from those hard to get to areas, a twenty-seven inch long section of airline tubing is taped to the underside of the rod using electrical tape. One can drive fish out of a deep hole by attaching your quinaldine bottle to the end of the airline tubing and squeezing the bottle to force the drug deep into the hole to drive fish out into your net. Drill two quarter inch holes three inches apart in both a plastic pipe sheath (ten inches long and one inch diameter) and the right hand side of the dive belt. A large plastic cable tie will secure the plastic pipe sheath to the dive belt. The probe is placed in the sheath when not in use and is secured by a piece of six inch elastic chord connected to a swivel eye snap. This snap connects to the probe to prevent loss during diving (see figure 4).

This dive belt with its fish container and probe is inexpensive and easy to make. It will prove very valuable in fish collecting.





Chloramine Removal from Municipal Water Supplies for Aquatic Organisms

by Gary Zimmerman, Department of Physiology, University of California, Los Angeles, California, 90024, U.S.A.

BACKGROUND

Until recently, most municipal drinking water in the United States was disinfected by the addition of chlorine either in the form of chlorine gas or as hypochlorite ion (bleach is sodium hypochlorite, NaOCl). The intention of this procedure is to raise the levels of free chlorine residualS in the water. Extremely little molecular chlorine (Cl_2) is present in water at pH values greater than 3.0 (National Academy of Sciences 1980). Municipal water systems are usually adjusted to a slightly alkaline pH to retard pipe corrosion, so free chlorine residualS in drinking water mainly refers to the hypochlorous acid (HOCl) and the hypochlorite ion (OCl^-) formed when chlorine or hypochlorite reacts with water. These compounds are disinfectants by virtue of their being oxidizing agents. The most effective water disinfectant in this scheme is the HOCl, whose concentration is determined by the pH of the solution:

hydrolysis:

$$Cl_2 + H_2O \text{ <---> } HOCl + H^+ + Cl^-$$

$pK = 3.35$ at 25°C
(Piedrahita 1984)

ionization:

$$HOCl \text{ <---> } H^+ + OCl^-$$

$pK_a = 7.54$ at 25°C
(Gray et al. 1978)

Many cities have begun switching to the use of chloramines for their water disinfection because potential carcinogens (trihalomethanes such as chloroform) are formed when chlorine alone is used. Chloramines are formed when HOCl combines chemically with ammonia (NH_3):

$$HOCl + NH_3 \text{ <--> } NH_2Cl + H_2O$$
monochloramine

$Keq = 1.5 \times 10^{11}$ (Gray et al. 1978)

$$NH_2Cl + HOCl \text{ <--> } NHCl_2 + H_2O$$
dichloramine

$$NHCl_2 + HOCl \text{ <--> } NCl_3 + H_2O$$
trichloramine
(nitrogen trichloride)

The type of chloramine predominant in a solution depends on the pH and the relative concentrations of the various reactants. Monochloramine is prevalent at pH's above 7.5 if the molar ratio of chlorine to ammonia is at or below one. (National Academy of Sciences 1980). Di- and trichloramines do not appear in significant amounts until the pH drops below 5.5 and 3, respectively. Because of the pH adjustment of municipal water supplies, nearly all chloramines will be in the mono- form as the water comes out of the tap.

Residual chlorine in all forms is toxic to aquatic organisms in very low concentrations (Brungs 1973). Chlorine (as HOCl and OCl^-) probably oxidizes sulfhydryl groups of enzymes thus inactivating them permanently (Alabaster and Lloyd 1982). Once an organism is poisoned it will often not recover even if placed in acceptable water (Panniker 1960). Chloramines are toxic to aquatic organisms (and to humans undergoing hemodialysis) because they bind to and oxidize hemoglobin, causing methemoglobinemia, a form of hemolytic anemia, much as exposure to carbon monoxide does (Groethe and Eaton 1975). If chloramine poisoning is not too severe, and the organisms are removed to acceptable water in time, they may recover. While toxic effects of residual chlorine to organisms utilizing hemocyanin for oxygen transport are known (Alabaster and Lloyd 1982), the mechanism of toxicity has not be documented.

How to effectively and efficiently remove sufficient chloramines is a point of some debate and considerable uncertainty even amongst officials in the various water departments. Chloramines can break down in water to hypochlorous acid and NH_3, but this reaction is slow ($T_{½}$ = 10 hours) and not thermodynamically favored (Margerum et al. 1978); merely allowing water to stand before using it for aquatic organisms will not be effective. The literature suggest that, apart from allowing the water to stand, what works for chlorine works for chloramines, however treatments for chloramine removal require more time.

One way to remove chloramines is by breakpoint chlorination. This involves adding excess chlorine to remove the combined chlorine residual. It uses up the ammonia in the water by producing nitrogen gas and nitrous oxide.

$$2NH_2Cl + HOCl \text{ ----> } N_2 + H_2O + 3HCl$$

$$NH_2Cl + NHCl_2 + HOCl \text{ ----> } N_2O + 4HCl$$

(Piedrahita, 1984)

Further addition of chlorine yields free chlorine residual in the water which may be dealt with in the usual way. This method is not usually tried if dechlorination is the ultimate goal.

Ultraviolet radiation has also been used for removal of HOCl and may be 100% effective (Seegert and Brooks 1978):

$$HOCl \text{ ---u.v.--> } H^+ + Cl^- + ½O_2$$

This method will also work to remove chloramines (Armstrong and Scott 1974), however due to the slow flow rates and/or intense u.v. systems required this is not a very cost effective method.

SUGGESTED WATER TREATMENTS

For aquatic organisms the U.S. Environmental Protection Agency (1975 and 1976) recommends that levels of total chlorine residual be maintained below 2-10 micrograms/liter (parts per billion), depending on the organism concerned. Alabaster and Lloyd (1982) report that some salmonid species of fish are sensitive to residual chlorine levels down to 1 microgram/liter. The American Public Health Association recommends that levels be maintained below 0.5 micrograms/liter (cited in Seegert and Brooks 1978).

Bear in mind that to use these criteria one must know the TOTAL chlorine residual. Many kits only test for the aforementioned free chlorine residual. Chloramines, a component of combined chlorine residual, do not appear in these tests. Total chlorine residual includes both free and combined chlorine. Also, most test kits' sensitivities and lower limits are at least an order of magnitude greater than the criteria. A test kit may show no chlorine residual if there is anything less than 50 micrograms/liter; this would not be a sufficiently sensitive test for aquatic organisms.

Granular Activated Carbon

Granular activated carbon (GAC) serves as an adsorbant and catalyst for some reactions in water systems (National Academy of Sciences 1980). Commercially available GAC systems will remove most, but not all, of the chlorine residual including both free and combined (Seegert and Brooks 1978). Chloramine removal is about 10 times slower than free chlorine removal (Snoeyink and Markus 1973).

GAC actually breaks the hypochlorous acid, hypochlorites and chloramines down, rather than merely adsorbing them and holding on (National Academy of Science 1980). For monochloramine Bauer and Snoeyink, 1973, proposed that the molecule is broken down in the following reactions:

$$NH_2Cl + H_2O + C^* \text{ --------> } NH_3 + H^+ + Cl^- + CO^*$$

$$2NH_2Cl + CO^* \text{ ----------> } N_2 + 2H^+ + 2Cl^- + H_2O + C^*$$

Where C* represents the activated carbon and CO* represents the carbon with a layer of surface oxides. New GAC is C* and so at first will produce mainly NH_3 from the monochloramine. It is therefore desirable to expose the GAC to monochloramine for about 24 hours (as by running municipal water through the column) before using the column for water treatment. This acclimation time allows surface oxides to form on the GAC and decreases the NH_3 in the effluent. There will still be some NH_3 coming out of the column and this has some consequences for subsequent treatment of the water.

These reactions were reconfirmed by Scaramelli and DiGiane, 1977. They found that while the ratios predict about a third of the monochloramine yielding NH_3 at equilibrium, the buildup of surface oxides to equilibrium levels slows appreciably at the point where about half the monochloramine is producing NH_3. Even after two weeks of continuous use this ratio was maintained.

Note that treatment via GAC will also acidify the water somewhat.

As the monochloramine/GAC reactions are relatively slow, Scaramelli and DiGiane, 1977, recommended a contact time of at least 16 minutes. They also noted that dissolved organics in the water hinder these reactions; that is important if recycled wastewater is being treated by GAC. Kim and Snoeyink, 1980, found that influent NH_2Cl concentration, flow rate and contact time, and GAC particle size affect the performance of GAC columns.

Seegert and Brooks (1978) found that for various commercial GAC systems (Bruner-Calgon model AC 16FF, Illinois Water Treatment models CC-230 and CM-230, and Continental H_2O Services model 370) operated at or below their rated flow rates, residual chlorine levels were kept well below 100 micrograms/liter for months or years. A large capacity GAC system was found to be passing only 70 micrograms/liter after 3 years of continuous operation. Systems with more GAC, such as two-stage systems, seemed to allow higher flow rates, but did not appreciably decrease the amount of chloramine in the effluent water. To ensure high levels of chloram-

ine removal, do not exceed the rated flow rate for the unit used. Even so, remember that after less than a day the GAC will not be removing all of the residual.

Chemical Reduction

Once the bulk of chlorine/chloramine have been removed by adsorption/breakdown on GAC, the small residual can be chemically broken down in less than one minute by sodium thiosulfate ($Na_2S_2O_3$) or sodium sulfite (Na_2SO_3) (Coventry and Miller 1935; Beeton et al. 1976; Seegert and Brooks 1978). Only one of these two compounds is necessary.

$$2Na_2S_2O_3 + NH_2Cl + 2H_2O \text{ ----> } Na_2S_4O_6 + NH_4OH + NaOH + NaCl$$

(Coventry et al., 1935)

(The reaction for sodium sulfite was unavailable in the literature.)

Beeton excluded thiosulfate from consideration in his study owing to a potentially deleterious effect due to the tetrathionate [**Editor's Note:** the tetrathionate ion is an even stronger reducing agent than thiosulfate and will participate further in the reaction with the monochloramine, essentially resulting in an overall better preformance of the thiosulfate as a dechlorinating agent] product, however both sodium thiosulfate and sodium sulfite have been used as dechlorinating agents with success for many years. The amount added is determined by the amount of total chlorine residual and should be a small amount considering the chlorine residual values expected in the GAC effluent.

Amount added may be calculated by the following ratios:

7 thiosulfate: 1 chlorine residual by weight
or
6 sulfite : 1 chlorine residual by weight

(Piedrahita, 1984)

Assuming the GAC effluent has 70 micrograms/L chlorine residual (a safe and conservative assumption) one would add 490 micrograms of thiosulfate per liter or 420 micrograms of sulfite per liter. This may be achieved in a constant flow system via a relatively inexpensive chemical metering pump.

These amounts are in excess of what is stoichiometrically required, however they allow for incidental decomposition of the additives. Excess amount of thiosulfate or sulfite are relatively non-toxic to aquatic organisms (Pyle 1960; Beeton et al. 1976), so it is better to use a slight excess rather than too little. As thiosulfate and sulfite are relatively inexpensive and ostensibly non-toxic, one may elect to skip the GAC altogether, however, this method is not recommended due to the uncertain effects of high levels of sulfates and sulfites. If treated tapwater is being used to make up for evaporation from a closed system the levels of sulfate or sulfite will build up and necessitate occasional complete water changes.

[**Edtior's Note**: Sodium hydroxymethanesulfonate and it's solution (Amquel) effectively dechlorinates and detoxifies ammonia in one step.]

Ammonia

Both the GAC and the sulfate/sulfite reactions with monochloramine yield ammonia. Ammonia in water may take two forms:

$$NH_4^+ + H_2O \text{ <--> } NH_3 + H^+ + H_2O$$

pK_a = 9.25 at 25°C
(See calculations)

Ionized ammonium (NH_4^+) is not highly toxic but the unionized ammonia (NH_3) is very toxic. Most test kits measure total ammonia nitrogen (or TAN) which is the sum of NH_4^+ and NH_3, reported in terms of weight of nitrogen. It is necessary to know how much of the TAN is in the toxic NH_3 form. The concentration of NH_3 is determined by pH, temperature, and ionic strength of the solution. Proportion of total ammonia as NH_3 increases as pH and temperature increase, and as ionic strength decreases (see tables 1 and 2).

The concentration of NH_3-N should be under 0.02 mg/L for aquatic organisms (U.S.E.P.A. 1976).

To use the proportion values given in the tables, one would test for TAN, and multiply the value obtained by the appropriate factor for one's system. If the NH_3-N concentration calculated is above 0.02 mg/L it must be removed before the water is used for aquatic organisms. An optimally operating biological (undergravel) filter may be able to remove the ammonia via nitrification. Bacterial growth on the GAC may aid in this process (Barrett 1984), but bacterial interactions with GAC are not fully understood (National Academy of Sciences 1980).

Clinoptilolite (a.k.a. ammo chips, etc.) is a natural zeolite ion exchanger with a high affinity for NH_4^+ -- it grabs on to NH_4^+ ions and compensates by Letting go of sodium (Na^+) ions; it will exchange one ion for the other. As the NH_4^+ is removed by the exchanger the equilibrium brings down the NH_3 levels in the water. Clinoptilolite may be regenerated by immersion to a concentrated Na^+ solution where it will let go of the NH_4^+ and grab more Na^+. For this reason clinoptilolite and similar exchangers may NOT be used in saltwater or brackish water systems, but may be used to treat freshwater before the water is added to these systems. Clinoptilolite grains are a good medium for bacterial growth which may impair their exchange capabilities (Piedrahita 1984).

Clinoptilolite will remove about 1.6 meq NH_4^+-N/gm zeolite (Piedrahita 1984) 1.6 meq NH_4^+-N/gm zeolite x 14 mg NH_4^+-N/meq NH_4^+-N = 22.4 mg NH_4^+-N removed/gm zeolite. [**Editor's Note**: The author had originally used the word "resin" to refer to the clinoptilolite; resins, by definition are synthetic plastic materials, clinoptilolite is a naturally occuring zeolite mineral]

How long a column will last before it must be regenerated thus depends on the concentration of ammonia in the input water and the flow rate. Once the ammonia levels begin to rise in the efflu-

ent water they will probably rise very quickly, depending on column design.

Municipalities that use chloramines typically maintain the concentrations between 0.5 to 2.0 mg/L (as total chlorine residual). Some localities receive water from more than one source and the relative contributions are adjusted continuously. While the Metropolitan Water District of Southern California has told me that the water leaving their plant will have 1.5 mg/L chlorine residual and 0.5 mg/L TAN from their chloramine treatment (Barrett 1984), the amount of water that the Los Angeles Department of Water and Power uses from MWD depends on the availability of other water sources. Usually this amount is less than 5%, however occasionally LADWP has needed to use 100% MWD water. As the sources of water are never known with certainty in these situations, it is best to design water treatment systems conservatively; if the municipal water supply has any chloramines at all added, assume that it is all chloraminated.

TABLE 1. PROPORTION OF TOTAL AMMONIA AS NH_3 IN FRESHWATER (μ = 0)

Temperature (°C):	10	15	20	25
pK_a (= pcK_a):	9.74	9.57	9.41	9.25
pH				
5.0	.0000182	.0000269	.0000389	.0000562
5.5	.0000575	.0000851	.000123	.000178
6.0	.000182	.000269	.000289	.000562
6.5	.000575	.000850	.00123	.00178
7.0	.00182	.00268	.00288	.00559
7.5	.00572	.00844	.0122	.0175
8.0	.0179	.0262	.0374	.0532
8.5	.0544	.0784	.110	.151
9.0	.154	.212	.280	.360
9.5	.356	.460	.552	.640
10.0	.645	.729	.796	.849

TABLE 2. PROPORTION OF TOTAL AMMONIA AS NH_3 IN SEAWATER 32-36 PPT (μ= 0.7 M)

Temperature:	10	15	20	25
P^cK_a:	9.96	9.80	9.63	9.48
pH				
5.0	.0000110	.0000158	.0000234	.0000331
5.5	.0000347	.0000501	.0000741	.000105
6.0	.000110	.000159	.000234	.000331
6.5	.000347	.000501	.000741	.00105
7.0	.00110	.00158	.00234	.00330
7.5	.00346	.00499	.00736	.0104
8.0	.0108	.0156	.0229	.0321
8.5	.0335	.0477	.0690	.0948
9.0	.0988	.137	.190	.249
9.5	.257	.334	.426	.512
10.0	.523	.613	.701	.768

See Calculations page for the methods used to generate these tables.

CALCULATIONS

Ionic strength of seawater (μ):

$$\mu = (19.9273\ S)/(1000 - 1.005109\ S)$$

where S = salinity in parts per thousand (Whitfield 1974)

Effective ionization constant for $NH_4^+ + H_2O <--> NH_3 + H^+ + H_2O$ in freshwater ($\mu = 0$):

$$pK_a = 0.09018 + (2729.92/T)$$

where T = temperature in degrees Kelvin (Emerson et al., 1975)

Conversion of effective ionization constant K_a (based on ion activities) to actual ionization constant ^cK_a (based on real ion concentrations):

$$p^cK_a = pK_a + [(.5(z^2)\mu^{0.5})/(1 + \mu^{0.5})]$$

where z is the charge of the ion in question and μ is the ionic strength of the solution (Piedrahita, 1984)

From these equations the values of p^cK_a at various temperatures were determined:

	Temperature (°C)			
	10	15	20	25
pK_a:	9.74	9.57	9.41	9.25
p^cK_a:	9.96	9.80	9.63	9.48

Determination of proportion of total ammonia as NH_3 (α_{NH3}):

$$\alpha_{NH3} = \frac{1}{1 + 10^{p^cK_a - pH}}$$

(Piedrahita, 1984; Bower and Bidwell, 1978)

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Design and Construction of a Wave Pulse Tank

Mr. Craig J. Hoff, Professor of Mechanical Engineering; Daniel O'Connor (Author), Robert Koch, Michael Kowalczyk, Michael Pruski, Michael Sawdon, Duane Hartsell.

INTRODUCTION

As a senior project for Lawrence Institute of Technology's Mechanical Engineering curriculum, a controlled marine ecosystem was designed and constructed. A 150 gallon glass aquarium was used along with newly designed subgravel and outside biological filters, and a time-controlled wave pulse wedge which creates wave pulse action.

During preliminary discussions with Daniel Marino and Edward Bromekowski of the Cleveland Aquariums about designing our marine aquarium, the main topic was how to "move the water". Mr. Marino discussed the subject of wave pulse action and the various degrees of success others have had in incorporating mechanisms to provide a good water movement.

Two of the most significant developments in moving water display tanks are the surge channel display at Vancouver Public Aquariums and the dump bucket system being used at the New England

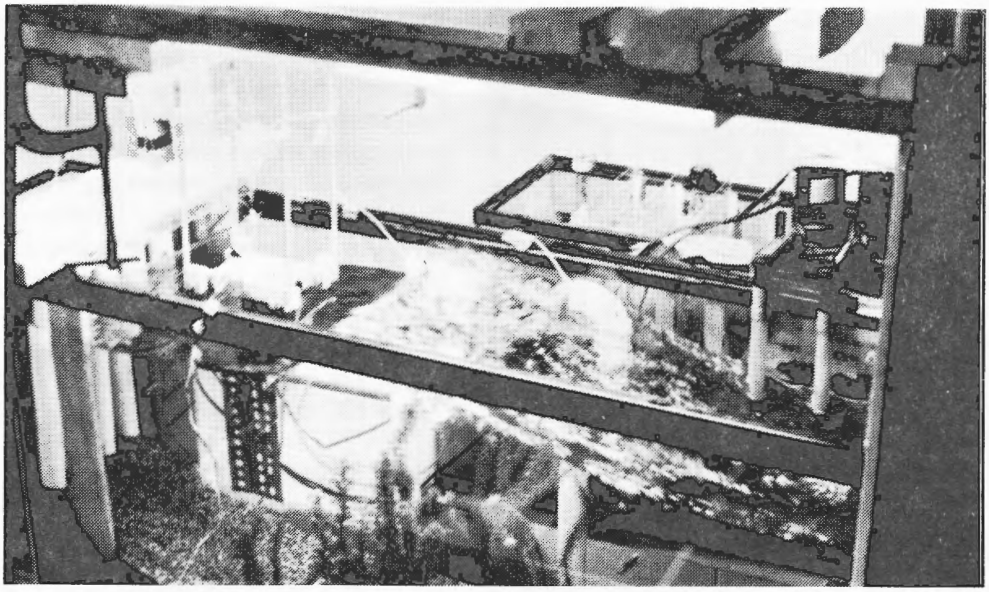


Figure 1. Wave Created by Wave Pulse Wedge.

Aquariums. The surge channel display uses a hydraulically operated paddle in a tank which is divided into two sections. One section contains the paddle system and the other section (viewing section) receives the surge of water produced in the paddle section. This system has achieved a good deal of success but the two-section tank takes up too much of the viewing area space. The dump bucket method of generating waves uses water, pumped into a bucket above the viewing tank, which is allowed to collect until it is dumped into the tank. The lack of timing control in this system limits the effects of waves generated.

The wave pulse wedge system we have designed creates a time-controlled wave pulse, while minimizing the space needed for operating the mechanism. A hollow wooden wedge is lifted vertically by an electric motor which is controlled by two timing relays. The wedge is guided by a guide compartment which is lifted into one end of the tank. The complete system is inexpensive to construct and is easily removed for maintenance.

DESCRIPTION

A standard size 150 gallon glass aquarium was used as our research tank. The aquarium is supported by a wooden stand especially designed to support auxiliary tanks, pumps and light fixtures. The wave pulse wedge assembly, which is separate from the main support stand, is composed of three parts:

A) Guide Compartment
B) Driving Unit
C) Wedge

Guide Compartment

The guide compartment, which fits inside the end of the 150-gallon aquarium, is a three-sided rectangular box, 71.5 inches long x 15.75 inches wide x 14.5 inches deep (see figure 4).

The compartment was constructed of 3/4-inch plywood with three coats of fiberglass resin applied to all wetted surfaces. Aluminum tracks were set inside the compartment for guiding the wedge. The complete guide compartment is supported by three 8-foot long wolmanized wood beams. The wood was donated and was not a design consideration per se. When this unit is lifted into position in the tank, the guide compartment is centered 1 inch above the gravel.

Drive Unit

The driving unit is composed of a 1/3 hp electric motor with a pulley attached to the shaft, and two timing relays which act as controls. This assembly, then attached to the top of the guide compartment, controls the action of the wedge (see figure 3).

As electricity is supplied to the circuit, one timing relay is energized and controls the time electricity is supplied to the motor. During this period, the wedge is lifted until the first timer's circuit is opened and control goes to the second timing relay. The second timing relay is connected to the first timing relay and de-energizes the motor, which in turn allows the wedge to drop freely into the tank, guided by the aluminum channels in the guide compartment. As the circuit of the second timing relay is opened, control is returned to the first timing relay, the motor is energized, and the wedge is lifted again.

Wedge

The wedge was constructed of 3/4-inch plywood and is 20.00 inches long x 15.25 inches wide x 14.25 inches deep at the top. The vertical shearing angle of the wedge to the water is 35.5 degrees. The top portion of the wedge is open to allow weights to be placed inside (see figures 4 and 1). The wedge has three coats of fiberglass resin with the bottom angle and corners having two additional layers of fiberglass cloth and resin for sealing and strength. The wedge is attached to the pulley by a 3/16-inch steel cable and is guided by four nylon rollers which slide in the channels provided inside the guide compartment. The wedge was designed to utilize the entire submerged area of the guide compartment so that the maximum area of the wedge face would generate waves. Another constraint in the wedge design was to limit the volume, or displacement, of the wedge in order to decrease the buoyant effect. To overcome the buoyancy, and allow greater penetration of the wedge into the tank, weights are added in the open top of the wedge. The maximum weight of both the wedge and extra weights is limited by the lifting capability of the 1/3-hp electric motor, this being 65 pounds. However, to increase the mechanical advantage of this system, a set of pulleys could be used to decrease the load on the motor.

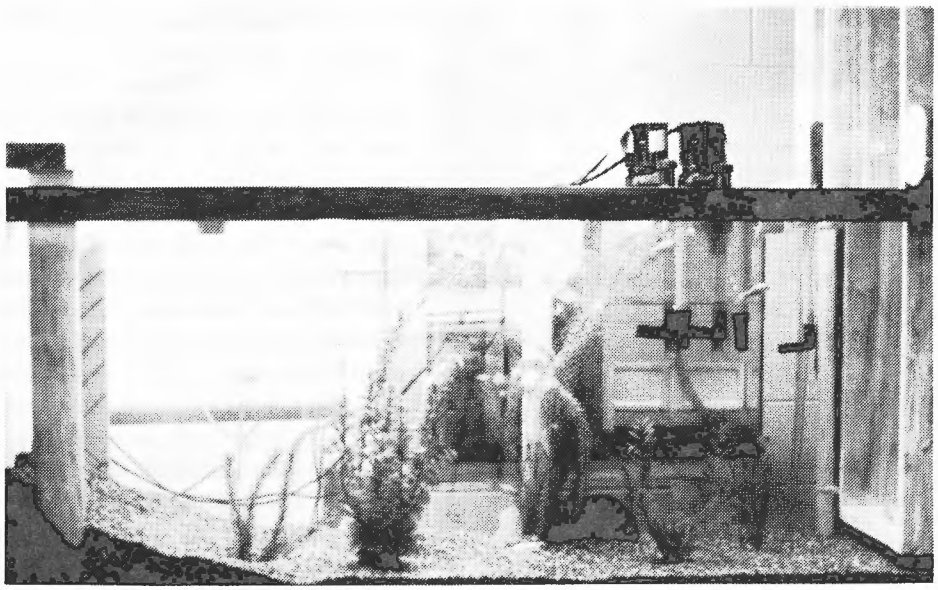
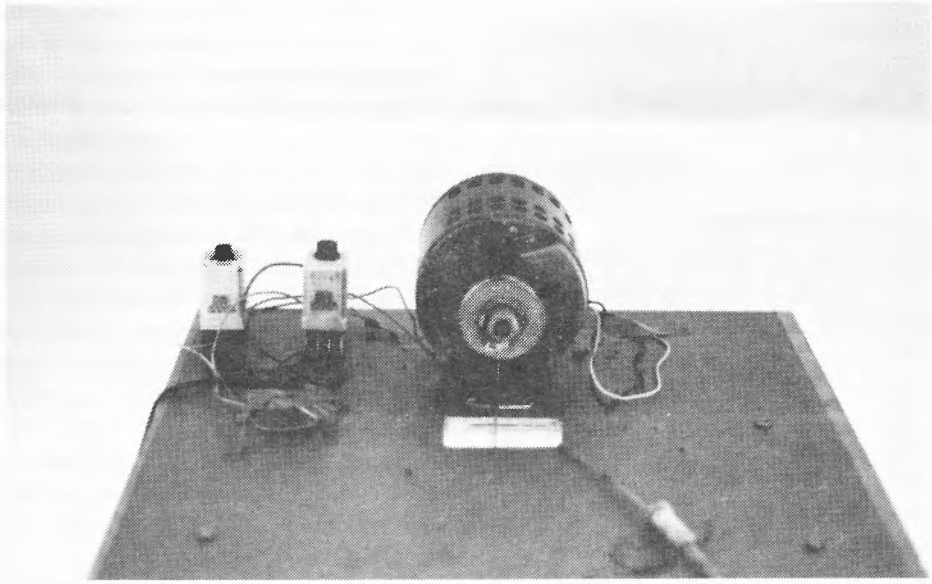


Figure 2. Front View of Aquarium.

Figure 3. Driving Unit Assembly.



EVALUATION

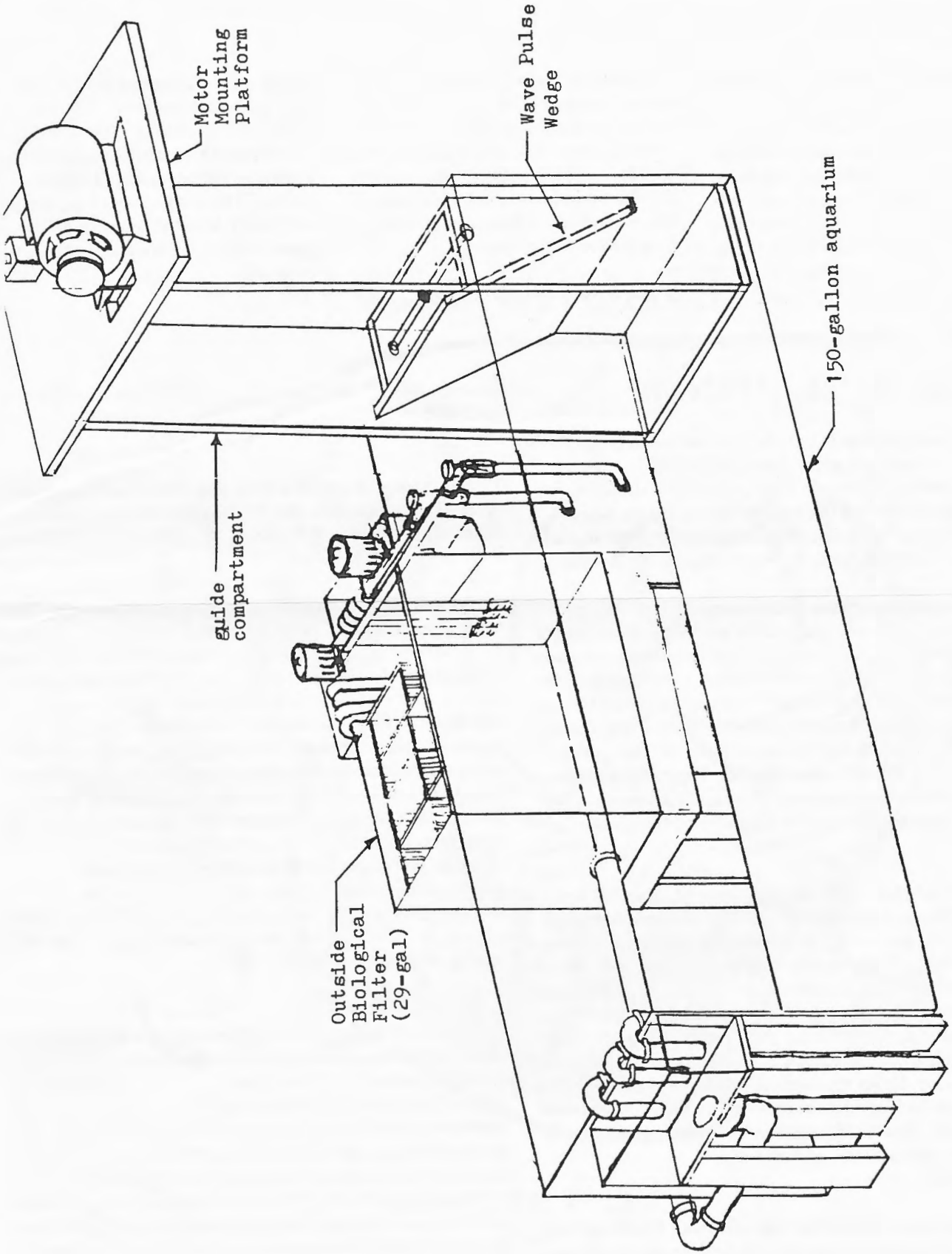
The wave pulse wedge system is effective in generating regulated wave patterns on the surface of the tank, and also creates tremendous sub-surface flow. The surface wave amplitude is controlled by the height at which the wedge is lifted from the water. As the wedge plunges into the tank from greater heights, more water is displaced and wave amplitude is increased. The period of the wave is controlled by the timing relays, which regulate the wedge lifting intervals.

Examination of the surface waves revealed harmonic wave patterns which were being distorted by the superposition of the reflected wave from the opposite end of the tank. These distorted waves did not fit the description of wave patterns indicative of the "near shore conditions" we were trying to duplicate. If the tank were lengthened, the wave would lose some of its energy and dissipate to allow more natural frequencies. This solution was beyond the scope of our project but would be worth the effort of future project groups. A set of plexiglass louvers were installed in our tank at the end opposite the wave pulse wedge to dissipate the reflected waves. The louvers worked well enough for our purposes, although some sloshing occurred at this end of the tank. The louvers did allow us to achieve a more natural damped harmonic wave, which looks similar to waves breaking along the shore.

SUMMARY

The system we have developed works very well for our 150 gallon aquarium. Although the motor, wood and timing relays were donated to us, this wave pulse system should be easily adaptable to any public display tank for a reasonable cost. The advantages of this wave pulse wedge system are 1) principal of operation is simple, 2) repairs are easy to affect because the entire system is portable, 3) the wave effects produced are excellent simulations of near-shore conditions in an ocean.

Figure 4. Overall Sketch of Seawater System.



NOTE - Worthy

NOTES FROM THE SHEDD AQUARIUM

Brian DuVall, our assistant curator will be leaving us to become curator of the New Jersey State Aquarium, construction of which will begin soon. This means that there will be yet another "graduate of the Shedd school of aquariology" out there at another aquarium. As far as I can figure, we have 8 grads out there, including the curator of fishes at Seaworld - Orlando.

We have a 85 foot research vessel which we keep docked in Miami. We utilize it for collecting expeditions, and public education trips. The ship is available for rent to other institutions, time permitting. In the past, Steinhart, University of Miami, and others have used it. Contact Roger Klocek if interested.

We are still looking for a group of 6 legally collected Garibaldi. From time to time we have excess stock available for trade, contact me for a list. There is a slim chance that we will be able to secure a one time only shipment of fish from the red sea. This will be a very risky venture, so I don't know if anybody would be interested in tying in with it, but if so, give me a call.

ABSTRACT CORNER

The following abstracts have been provided to Drum & Croaker by the staff of the International Association of Aquatic Animal Medicine. For more information on membership, contact Dr. Beverly Govan-Dixon, Secretary/Treasurer of the IAAAM, Department of Biological Science, California State Hayward, Hayward, CA 94545.

Filter Diagnostic Testfor Fish Viruses
Minnesota Sea Grant researchers have been developing a new method for identifying infectious pancreatic necrosis virus (IPN) by filtering water through a membrane filter rather than working with fish tissues. Traditional testing involves sampling numerous fish, killing them and placing their tissues on cell cultures for seven to 10 days. This is expensive and very unpractical for small operations. Recent field tests show the membrane filter technique works as well as lethal testing methods for determining the presence of virus.

The method starts with a large amount of pond water filtered through a positively charged membrane filter which absorbs the positively charged virus. The virus is then released with a buffer solution. Ninety percent of the total virus is recovered in just 300 drops of buffer. The buffer is then placed in cell culture to detect the virus. Current efforts are centered upon detecting the virus on the filter itself, reducing the time to diagnosis by eliminating the cell culture requirement. Other research efforts are investigating the value of similar filters for the removal of virus from contaminated water. This could have major implications in a variety of fish industries including home
tropical fish.

Initial start up costs for the test are about $1000 and the water concentration technique can be done on site if basic laboratory equipment is available. For more information contact: Annette M. Larson (612) 625-6781 or Alice Tibbetts (612) 625-9790.

Fish Infected with Sphaerospora spp. Thelohan (Myxosporea) from Waters Enzootic for Proliferative Kidney Disease of Salmonids. Hedrick, R.P., Kent, M.L., Totha, R.J. Morrison, J.K.: (1988) J. Protozool. 35(1):13-18. Sphaerospores were found in three species of fish examined from waters known to be enzootic for proliferative kidney disease of salmonids. They were detected in the renal tubules of both hatchery reared rainbow trout exposed to infective stages of PKD and in chubs in the headwaters of a hatchery where PKD is enzootic. Sticklebacks collected near net pens where Pacific salmon had experienced a PKD epizootic were also found to harbor sphaerospores in the lumen of the kidney tubules. The latter two host species contained developmental stages of a myxosporidian in the blood and in the lumen of the kidney tubules similar to those of PKX, the causative agent of PKD in salmonid fish. The sphaerospores observed in rainbow trout are the first to be observed in this species. The similarity to previously observed developmental stages, rarity and presence of the sphaerospores in salmonid fish from a hatchery where PKD is enzootic, suggest that they are the most mature stage of the PKX myxosporidian yet observed. [SP]

Quantitative Characteristics of the Electrocortigraphic Sleep Stages in Bottle-nosed Dolphins (in Russian). Mukhametov, L.M.; Oleksenko, A.I.; Poliakova, I.G.: (1988) Neirofiziologiia (USSR) 20(4):532-538. Unihemispheric slow-wave sleep is the dominant type of natural sleep in bottle-nosed dolphins, demonstrated with quantitative ECoG analysis on four captive animals. All variants of the bilateral and unilateral synchronization make up 33.4% of the total recording time with unilateral slow wave sleep accounting for nearly 29 percent. Unihemispheric sleep tends to appear in each hemisphere alternatively. [JPS]