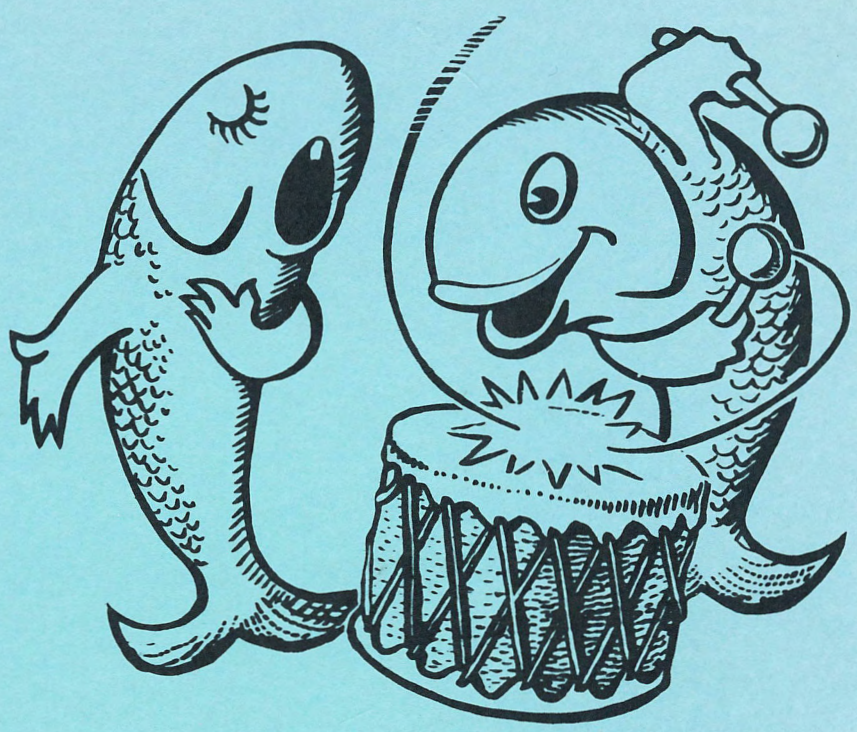

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A Highly Irregular Journal for the Public Aquarist

Spring 1979
volume 19 (79), number 1

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for Aquarists

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John H. Prescott
Executive Director
New England Aquarium

CONTENTS

ARTIFICIAL GORGONIANS

Marc Fleischmann
Exhibit Designer
New England Aquarium
(formerly at John G. Shedd Aquarium)

Reprinted from CURATOR,
quarterly publication of the
American Museum of Natural History
Volume 21/2

At the John G. Shedd Aquarium in Chicago, we are renovating our coral reef tank. This circular structure, forty feet in diameter and containing 90,000 gallons of salt water, represents a Caribbean coral reef with its associated life forms.

In several instances it was not feasible to use the actual organisms to decorate the tank (in our copper-treated water they die, and their skeletal remains deteriorate rapidly), and we were not satisfied with the artificial structures commercially available (there are few variations, and they deteriorate in salt water), so we were forced to develop techniques for duplicating some animal forms that occur in a coral reef. This article describes our method of simulating gorgonians, specifically the species nodding plexaurella (Plexaurella nutans), slimy sea plume (Psuedopterogorgia americana), warty eunicea (Eunicea calyculata), and bent plexaura (Plexaura flexuosa).

The basic structure of each colony is formed by sewing or welding pieces of twisted cord to braided polypropylene rope (Figures 1 and 2). Braided rope is used because it provides the best surface for adhesion of coatings and has the least tendency to unravel as assembly takes place. Polypropylene is preferred to other materials because it is a highly flexible fiber, resistant to deterioration, with a density in the 0.89-0.92 range, making it barely positively buoyant. This buoyancy, coupled with the flexibility, allows for realistic motion in response to the varying currents in the tank.

After the basic structure is assembled from the cord and rope (Figure 3), the first of several coatings is applied. The coating is a suspension of microsphere (B-18-A glass bubbles by 3M) in latex rubber (61-1000 latex molding compound by B. F. Goodrich). Microsphere provide the proper texture and add needed flotation to the structure. Latex rubber is used as a binder because of its high flexibility, nontoxicity, and quality of becoming more tenacious with age.

Polypropylene cord is spliced and welded together in a specialized technique for models of warty eunicea, (1) and polypropylene macrame cord loops are forced through polypropylene braid for most gorgonian models (2). The loops are cut (3) with a soldering iron, which seals the ends and prevents raveling. The structure is dipped in the latex/microsphere mixture (4). As it is withdrawn from the bucket, it is squeezed against the side with a stick (5) and then slapped against a board (6) to remove excess latex.

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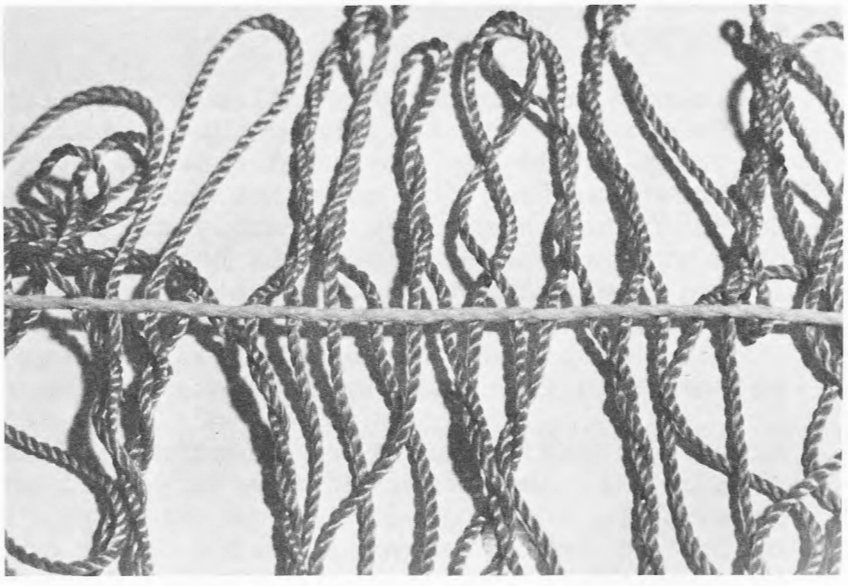

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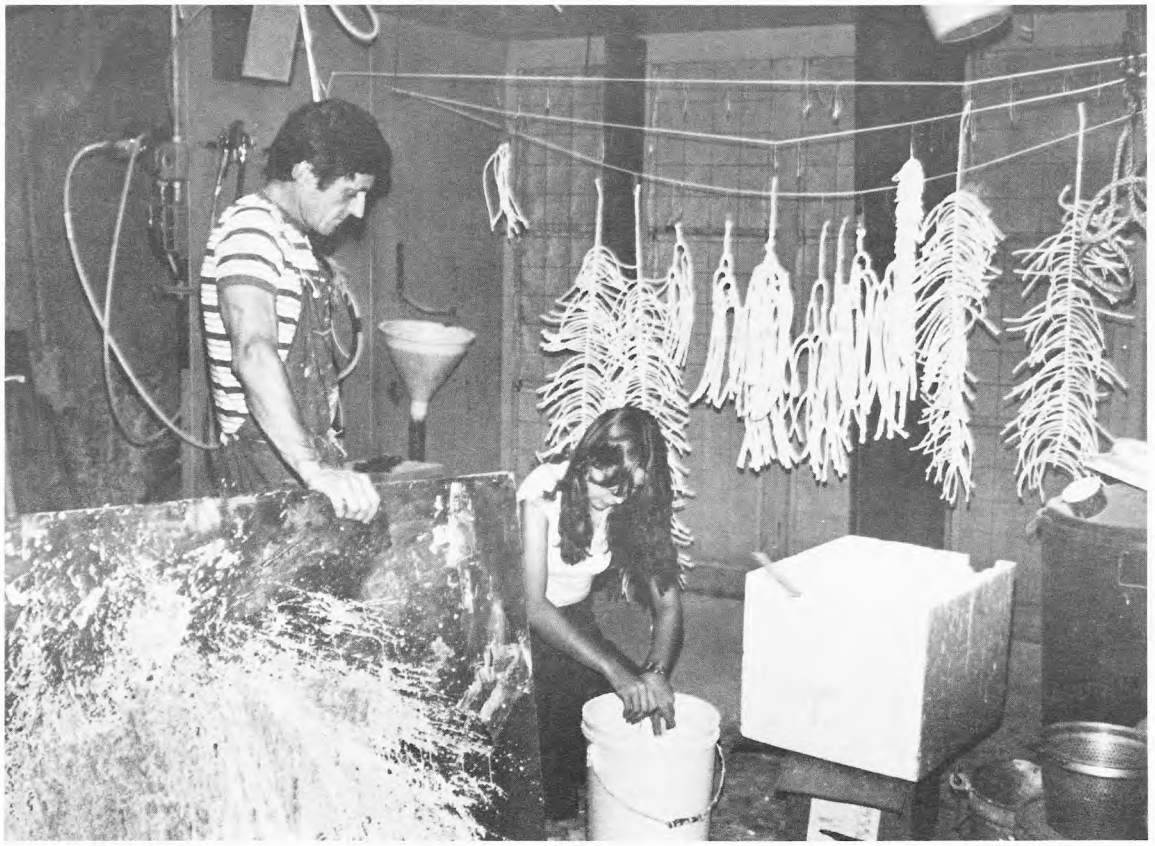

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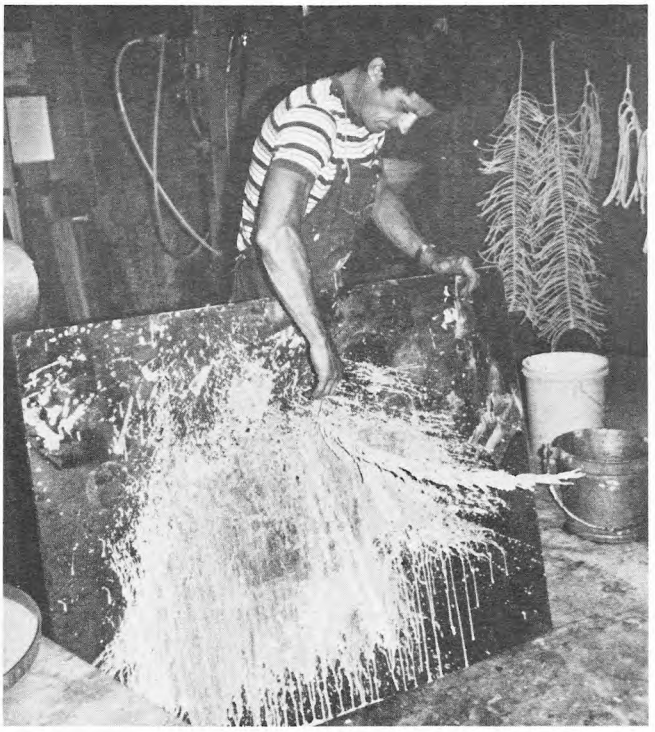

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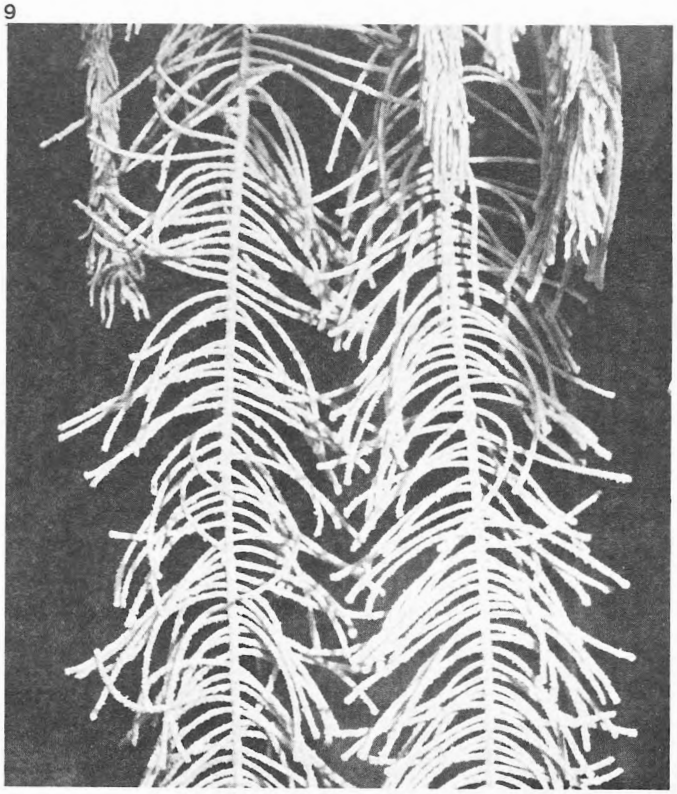

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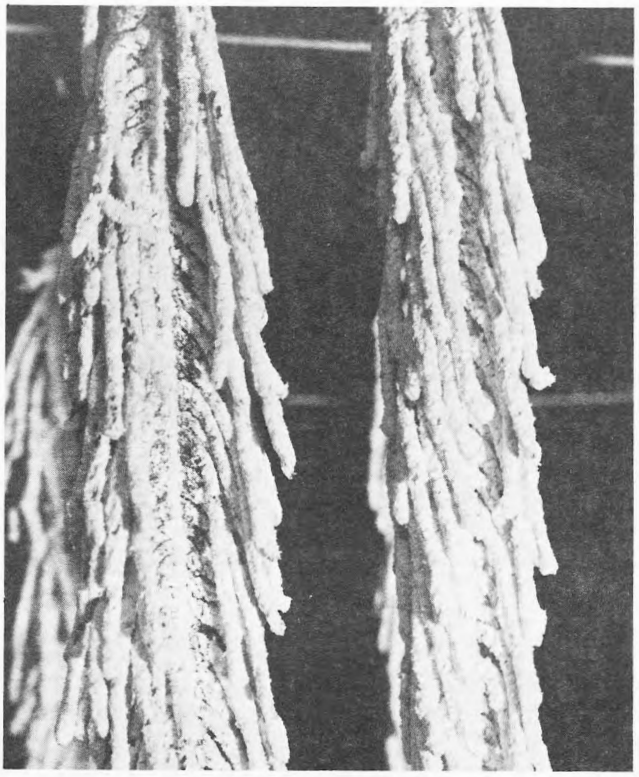

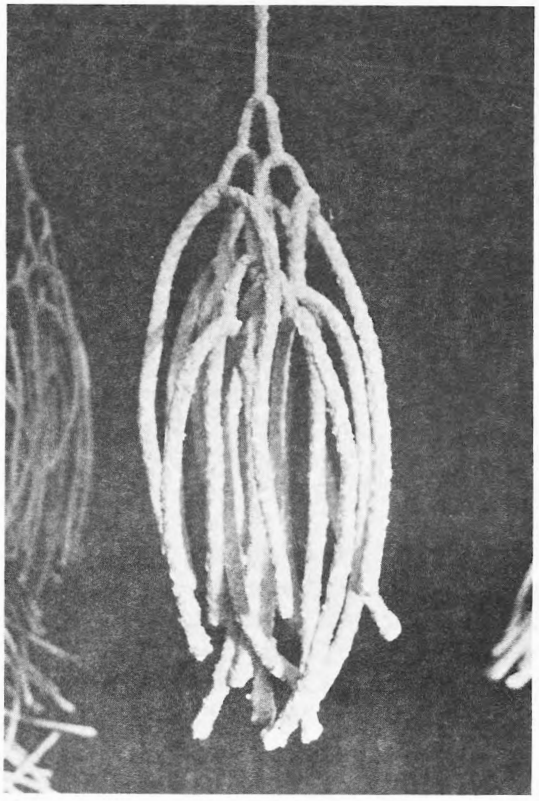

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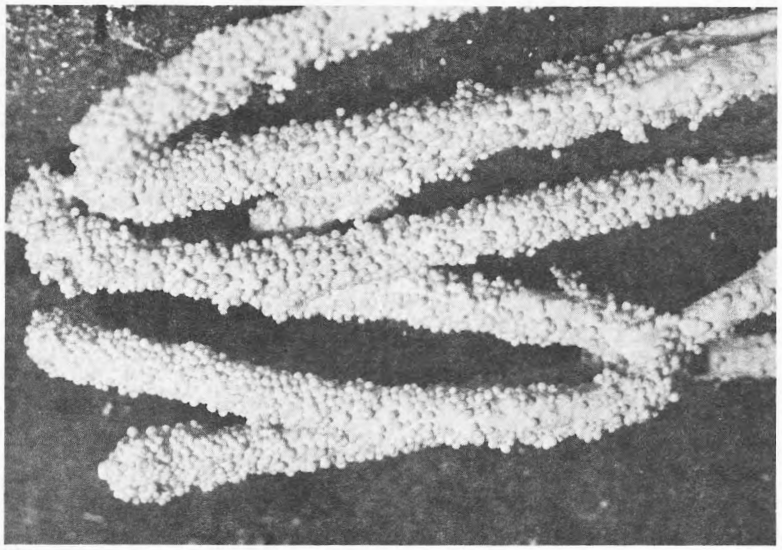

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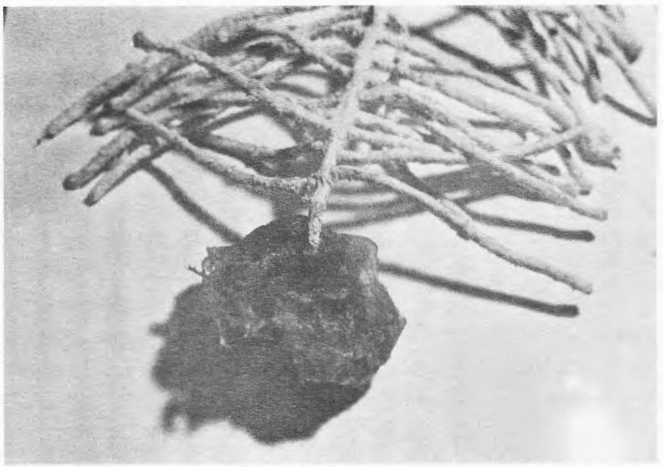
The still-moist structure is dipped in dry microspheres (7); excess microspheres are knocked off with a stick (8). The texture of the cord is gradually covered after one (9), two (10), and three (11) coatings of microspheres. In making the model of warty eunicea (10), preexpanded polystyrene beads are used in the final dipping (12).



Finished model with base attached.

The latex is thinned (one to one) from its mayonnaise-like consistency with distilled water in a large container (a five-gallon paint can, for instance). Microspheres are added until the final consistency is close to that of 30W (automobile engine) oil. Because it is loose and buoyant, the rope structure has to be forced into the suspension with a stick (Figure 4). After immersion, it is briefly drained (Figure 5) and then slammed soundly against a flat vertical surface (Figure 6). This slamming removes any excess rubber from the entire structure almost instantly; if the excess were only allowed to run off, the top would be too dry to work with by the time the bottom ends were free from excess rubber.

While still damp, the structure is flopped vigorously in a container of dry microspheres (an inexpensive styrofoam ice chest works well) (Figure 7). Excess microspheres are knocked off with a stick (Figure 8), and the model is hung to dry with the base end points down. Any strands that stick together after drying are carefully separated. The dipping process is repeated until the desired texture is obtained and the structure of the rope is completely hidden (Figures 9-12).

A base is constructed of thickened polyester resin combined with fumed silica (Aero-Sil 200 by DeGussa) and/or chopped fiberglass. Working on a piece of silicone rubber so that the resin will not stick to the surface, the base is applied to a knot tied in the end of the rope (Figure 13); the resin does not bond chemically to the polypropylene, so the knot supplies a mechanical connection.

The technique in making these models is simple, but a few suggestions will help ensure success:

1. All free ends of the rope and line should be welded to prevent unraveling.
2. BFG latex has a shelf life of only thirty days, after which polymerization will start to cause cracks in the coating.
3. The structures must be thoroughly dry before immersion in water. If the latex coating starts to turn milky white on contact with water, it is not fully cured.
4. The latex cures on contact with air, so the dipping and storage containers should be kept covered when not in use.
5. Only distilled water should be used to dilute the latex. A small amount of household ammonia can be added if the latex starts to coagulate too quickly.
6. The microspheres tend to gather on the surface of the latex immediately, forming a solid buoyant mass. They can easily be stirred back into the mixture.
7. Care should be taken not to rupture the microspheres when mixing them into the latex. Slow speeds and a soft-bladed paddle should be used.
8. Work should take place with adequate ventilation - especially when working with any microspheres, which are subject to inhalation.

When the gorgonian model is thoroughly dry, acrylic or latex paint is applied with a spray gun. When the paint is dry, the structure is ready to be added to the coral reef tank.

NORTH AMERICAN FISHES REPORTED AS HOSTS OF *AMYLOODINIUM OCELLATUM* (BROWN, 1931)

Adrian R. Lawler
Gulf Coast Research Laboratory
Ocean Springs, Mississippi

The parasitic dinoflagellate, *Amyloodinium ocellatum* (Brown, 1931), can cause mass mortalities of estuarine and marine fishes held in closed systems. Signs of the disease, various stages of the parasite, hosts, control measures, etc., have been reported previously (Brown, 1931, 1934; Nigrelli, 1936; Brown & Hovasse, 1946; Dempster, 1956, 1972, 1973; Lawler, 1972, 1977a, 1977b; Kingsford, 1975).

I have been studying this parasite since 1971. One portion of the studies has been to ascertain which Gulf of Mexico fishes are susceptible, and succumb, to this dinoflagellate species.

Concentrations of dinospores were maintained in various filtered, closed-system tanks by continually adding known susceptible hosts to the tanks. After the introduced fishes died, they were either left in the tanks for a while (so the dinoflagellate trophonts could encyst and fall off the fishes) or their gills (and the attached parasites) were returned to the tanks. Potential hosts to be tested were added to exposure tanks as they became available; they were examined near, or shortly after, death for the presence of dinoflagellates with the aid of microscopes.

Several thousand fishes of various species have been exposed to the dinoflagellate since 1971, resulting in the addition of 62 species of North American fishes to the list of those susceptible to the parasite (Table 1). Presently, the species is known to infect 111 species of 46 families of fishes in tanks in North America.

Portions of this study were supported by grants to Dr. R. M. Overstreet, GCRL, from the National Marine Fisheries Service, Project Nos. 2-85-R and 2-174-R.

Table 1. North American fishes reported as hosts of *Amyloodinium ocellatum*.

DASYATIDAE
* *Dasyatis sabina* (Lesueur)

OPHICHTHIDAE
* *Myrophis punctatus* Lütken
* *Ophichthus gomesi* (Castelnau)

CLUPEIDAE
* *Harengula jaguana* Poey

ENGRAULIDAE
* *Anchoa mitchilli* (Valenciennes)

SYNODONTIDAE
* *Synodus foetens* (Linnaeus)

ARIIDAE
* *Arius felis* (Linnaeus)
* *Bagre marinus* (Mitchill)

BATRACHOIDIDAE
* *Opsanus beta* (Goode & Bean)
* *Porichthys porosissimus* (Valenciennes)

GOBIESOCIDAE
* *Gobiesox strumosus* Cope

GADIDAE
* *Urophycis floridanus* (Bean & Dresel)

CYPRINODONTIDAE
* *Fundulus jenkinsi* (Evermann)

POECILIIDAE
* Gambusia affinis (Baird & Girard)

HOLOCENTRIDAE
1,2,3 *Holocentrus ascensionis* (Osbeck)

SYNGNATHIDAE
* *Hippocampus erectus* Perry
* *Syngnathus louisianae* Günther

PERCICHTHYIDAE
*,4,5 Morone saxatilis (Walbaum)

SERRANIDAE
* Centropristis philadelphica (Linnaeus)
3,4 Centropristis striata (Linnaeus)
3 Epinephelus adscensionis (Osbeck)
3 Epinephelus morio (Valenciennes)
* Epinephelus niveatus (Valenciennes)
3 Petrometopon cruentatum (Lacépède)
* Serraniculus pumilio Ginsburg
* Serranus subligarius (Cope)

GRAMMISTIDAE
* Rypticus maculatus Holbrook
3 Rypticus saponaceus (Bloch & Schneider)

CENTRARCHIDAE
* Lepomis macrochirus Rafinesque (held in 4 ppt sea water)

APOGONIDAE
3 Apogon maculatus (Poey)

POMATOMIDAE
4 Pomatomus saltatrix (Linnaeus)

CARANGIDAE
4 Caranx crysos (Mitchill)
*,4 Caranx hippos (Linnaeus)
* Caranx latus Agassiz
* Chloroscombrus chrysurus (Linnaeus)
4 Naucrates ductor (Linnaeus)
* Oligoplites saurus (Bloch & Schneider)
* Trachinotus carolinus (Linnaeus)
4 Trachinotus falcatus (Linnaeus)

LUTJANIDAE
3 Lutjanus analis (Cuvier)
3 Lutjanus apodus (Walbaum)
* Lutjanus campechanus (Poey)
*,3,6 Lutjanus griseus (Linnaeus)
3 Lutjanus jocu (Bloch & Schneider)
3 Lutjanus synagris (Linnaeus)
3 Ocyurus chrysurus (Bloch)

LOBOTIDAE
* Lobotes surinamensis (Bloch)

GERREIDAE
* Eucinostomus argenteus Baird & Girard

POMADASYIDAE

3 Anisotremus virginicus (Linnaeus)
3 Haemulon album Cuvier
3 Haemulon flavolineatum (Desmarest)
3 Haemulon macrostomum Günther
3 Haemulon plumieri (Lacépède)
3 Haemulon sciurus (Shaw)
* Orthopristis chrysoptera (Linnaeus)

SPARIDAE

* Archosargus probatocephalus (Walbaum)
* Lagodon rhomboides (Linnaeus)
4 Stenotomus chrysops (Linnaeus)

SCIAENIDAE

* Bairdiella chrysura (Lacépède)
* Cynoscion arenarius Ginsburg
* Cynoscion nebulosus (Cuvier)
4 Cynoscion regalis (Bloch & Schneider)
* Equetus acuminatus (Bloch & Schneider)
3 Equetus umbrosus Jordan ¢ Eigenmann)
* Larimus fasciatus (Holbrook)
*,3 Leiostomus xanthurus Lacépède
* Menticirrhus americanus (Linnaeus)
3,4 Menticirrhus saxatilis (Bloch & Schneider)
* Micropogonias undulatus (Linnaeus)
* Sciaenops ocellata (Linnaeus)

EPHIPPIDAE

*,3 Chaetodipterus faber (Broussonet)

CHAETODONTIDAE

2 Chaetodon capistratus Linnaeus
3,7 Pomacanthus arcuatus (Linnaeus)
3,4,6 Pomacanthus paru (Bloch)

POMACENTRIDAE

3 Abudefduf saxatilis (Linnaeus)

LABRIDAE

6 Thalassoma bifasciatum (Bloch)

SCARIDAE

3 Scarus coeruleus (Bloch)

MUGILIDAE

*,2 Mugil cephalus Linnaeus

BLENNIIDAE
* Chasmodes bosquianus (Lacépède)
* Hypsoblennius hentzi (Lesueur)
* Hypsoblennius ionthas (Jordan & Gilbert)

ELEOTRIDAE
* Eleotris pisonis (Gmelin)

GOBIIDAE
* Bathygobius soporator (Valenciennes)
* Gobioides broussonneti Lacépède
* Gobiosoma bosci (Lacépède)
* Gobiosoma robustum Ginsburg
* Microgobius gulosus (Girard)

MICRODESMIDAE
* Microdesmus longipinnis (Weymouth)

ACANTHURIDAE
3 Acanthurus chirurgus (Bloch)
3 Acanthurus coeruleus Bloch & Schneider

SCORPAENIDAE
* Scorpaena brasiliensis Cuvier

TRIGLIDAE
3,4 Prionotus carolinus (Linnaeus)
4 Prionotus evolans (Linnaeus)
* Prionotus roseus Jordan & Evermann
* Prionotus tribulus Cuvier

BOTHIDAE
* Citharichthys spilopterus Günther
* Etropus crossotus Jordan & Gilbert
* Paralichthys lethostigma Jordan & Gilbert

SOLEIDAE
* Achirus lineatus (Linnaeus)
* Trinectes maculatus (Bloch & Schneider)

CYNOGLOSSIDAE
* Symphurus plagiusa (Linnaeus)

BALISTIDAE
* Aluterus schoepfi (Walbaum)
3 Balistes vetula Linnaeus
* Monacanthus hispidus (Linnaeus)

OSTRACIIDAE

* Lactophrys quadricornis (Linnaeus)
3 Lactophrys trigonus (Linnaeus)

TETRAODONTIDAE

2 Canthigaster rostrata (Bloch)
3,4,8 Sphoeroides maculatus (Bloch & Schneider)
* Sphoeroides parvus Shipp & Yerger

DIODONTIDAE

*,3,4,8,9 Chilomycterus schoepfi (Walbaum)
3 Diodon hystrix Linnaeus

* Lawler (unpublished data)
1 Brown (1931)
2 Brown (1934)
3 Nigrelli (1940)
4 Nigrelli (1936)
5 Dempster (1956)
6 Kingsford (1975)
7 Valenti (1968)
8 Simkatis (1958)
9 Brown & Hovasse (1946)

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AN EVALUATION OF THE HOOK AND LINE METHOD TO OBTAIN WEAKFISH, *CYNOSCION REGALIS*, FOR ARTIFICIAL SPAWNING

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ABSTRACT

During May and June 1977, members of the Delaware Experimental Laboratory collected weakfish, *Cynoscion regalis*, by hook and line in the middle Delaware Bay. The purpose of this program was to take sexually mature adult fish and spawn them artificially. The resultant larvae would be utilized in behavioral and tolerance tests.

Of the 247 weakfish taken, all males were ripe but no females were considered mature enough to be spawned artificially.

While it is probably feasible to take ripe adults by hook and line, this method should not be relied on to the exclusion of other more traditional methods.

Since 1969, the Delaware Experimental Laboratory of Ichthyological Associates, Inc., located on the Appoquinimink River near Odessa, Delaware, has conducted behavioral and tolerance studies on estuarine fishes of the upper Delaware Bay, lower Delaware River, and Chesapeake Bay. These studies evaluate potential effects of thermal and chemical discharges in the study area. Study organisms include larvae and juveniles of the weakfish, *Cynoscion regalis*, an important sport and commercial species which occurs in the Delaware estuary (Schuler and Maiden 1975). However, the availability to standard collection techniques of sufficient numbers for testing is a major problem in working with this species. One solution is to artificially spawn adult weakfish and rear the young.

The weakfish supports a considerable sport and commercial fishery throughout much of its range, Florida to occasionally Massachusetts. Commercial gill net catches show that it enters

Delaware Bay in March or April and remains into November. Spawning occurs from May to September with most in late May or early June (Thomas 1971, Welsh and Breder 1923, Daiber 1957).

Available data shows that the earliest spawners are predominately large specimens weighing up to approximately 6.8 kg. Because of the large number of fish available during the early spawning period and the ease of capture by hook and line, effort was directed at these large weakfish during May and June 1977.

Although gill nets were considered in gear selections, it was felt that fish taken by hook and line would be in better condition. Ripe males and females taken were to be stripped in the field and the fertilized eggs transported to the laboratory to be reared under controlled conditions.

MATERIALS AND METHODS

A 36 ft. charter boat was hired on a daily basis to accommodate personnel, holding tanks, and gear. This size boat provided a suitable work and storage area, fish locating electronics, and an experienced captain who could maintain radio contact with other charter captains who often provided valuable catch information.

Spinning rods of 19.8-27.4 cm were used. Spinning gear is preferred by many anglers and seems especially suited for weakfish (Muller 1976). Artificial lures which resembled the small fishes on which large weakfish mostly feed (Thomas 1971) were used as bait. Following the captain's suggestion of adding a 76-127 mm strip of fresh cut squid to each lure resulted in increased catches. Fish were boated with a 55.8 cm diameter by 76.2 cm deep landing net with a bag of 88.9 mm stretched mesh knotted nylon. To minimize damage to the fish through abrasion and scale loss, the net was fitted with an inner liner of 19.1 mm stretched mesh knotless nylon webbing. Water temperature was measured daily. Fishing time averaged 36 man-hours per day.

The method of capture and handling was as follows: The charter boat was run to the vicinity of Brandywine Shoal (Fig. 1) near midbay and slowed to idle speed. When possible, fish were located through radio contact with other charter captains. If necessary, the depth finder was utilized to locate fish concentrations. When fish were located, the engine was killed and the boat allowed to drift. The depth finder was continually operated and observed periodically to maintain position over

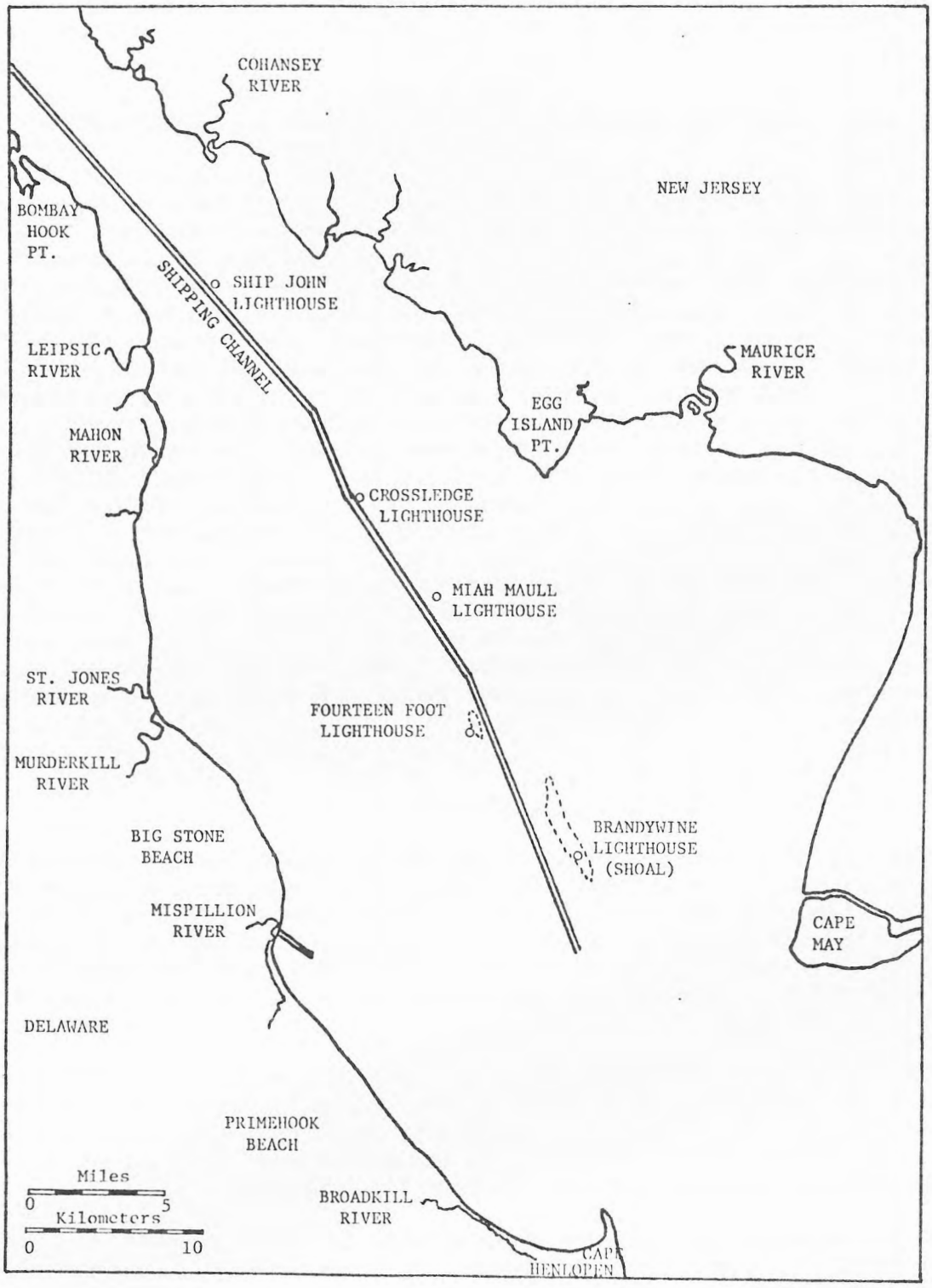

Figure 1. - The location of Brandywine Shoal and Lighthouse in the lower Delaware Bay.

the fish. When the flasher showed "no fish", a new search was begun.

Once fish were located and their depth determined, lures were rigged and cast to 18.3-27.4 m from the boat. The lure was allowed to drop through the water column to the approximate depth of the fish and then reeled in obliquely or variously jigged at individual preference. When fish appeared concentrated directly under the boat, vertical jigging was often employed. Captures were brought to the boat as quickly as possible; this often involved several minutes due to the depth of hookup, size of fish, and also to prevent fish loss due to tearing of the easily torn membranes around the mouth. Each fish was surrounded with the landing net, and before being lifted from the water, was anesthetized (usually within one minute) by spraying the gills with a 50 cc dosage of 1.0 ppt quinaldine. With the fish still in the water, the hook was removed, and the netted fish was lifted, sexed, examined for sexual condition and placed in one of the two 189.3-l aerated recovery tanks maintained at 28 ppt salinity. Most fish recovered in less than five minutes. Ovaries were examined for sexual maturity, and the general range of fish was recorded on each trip.

RESULTS

A total of eight collection trips taken from 13 May through 14 June yielded 247 weakfish (76 males, 171 females), a catch rate of 0.86 fish/hr (Table 1). Daily catch ranged from zero on 6 June to 54 on 20 May. Individual anglers took up to 16 fish/day. Fish weight ranged from 0.45 to 4.8 kg, but most weighed 2.3 to 3.6 kg. Water temperature increased from 15.5 C on 13 May to 22.0 C on 14 June.

Examination of sacrificed females taken on each trip indicated that only two were spent (i.e., had spawned). All others were green or near ripe and were sexually maturing with time (Table 1). All males were running ripe or would emit milt when slight pressure was applied to the area of the gonads.

From 13 through 18 May, 22 ripe males, 59 green females, 2 near-ripe females, and 2 spent females were collected. Weight ranged from 0.9 to 4.3 kg. At no time during the program were females taken which were considered ripe enough to be spawned artificially. On 17 May, two near-ripe females and one partially spent female were taken. These were stripped and the eggs fertilized and transported to the laboratory. Although some development was noted, all eggs died within 18 hr of fertilization. This

Table 1. - The date of catch, number of fish, catch/man hour and sexual condition of 247 weakfish collected by hook and line sampling from 13 May-14 June 1977.

Date of Catch	Temp. C	# Taken	#/man hour*	Weight Range kg	Ripe Males	Green Females	Near Ripe Females	Spent Female
13 May	15.5	29	0.81	1.36-4.31	13	15	0	1
17 May	16.5	27	0.75	1.36-3.63	6	18	2	1
18 May	15.2	29	0.81	.91-4.31	3	26	0	0
20 May	16.0	54	1.50	.91-4.76	27	12	15	0
24 May	19.0	45	1.25	.91-4.08	8	26	11	0
27 May	18.0	38	1.06	.91-3.63	11	7	20	0
6 June	-	0	0	0	0	0	0	0
14 June	22.0	25	0.69	.45-2.26	8	17	0	0
Total		247	0.86	.45-4.76	76	121	48	2

*The number of man hours fished averaged 36.0/day (288 total)

may have been due to premature fertilization and/or contamination from blood and ovarian tissue (Stephen Goldman, Ichthyological Associates, Inc., Pers. Comm.). The occurrence of only two spent females suggested that very little spawning had taken place.

On 20 May, 56% of 27 females weighing from 0.9-2.8 kg were near-ripe. On 24 May, 30% of 37 females weighing 0.9-4.1 kg were near-ripe. On 27 May, 74% of 27 females weighing 0.9-3.6 kg were near-ripe.

Several days of poor catches (2-5 fish/boat) were reported by charter captains during the first two weeks of June. Fishing during this time was hindered by bad weather, as on several occasions even the largest of charter boats remained at port or cancelled fishing activities early in the day.

On 6 June we took no fish and discontinued the program pending notice by the captain that fish were again being taken. Such notice was received on 12 June and on 14 June eight ripe males and 17 green females were taken. The lack of near-ripe females and smaller size of fish collected (0.45-2.30 kg) suggested that the first spawn had ended and that a second wave of smaller weakfish had entered the bay, a schedule reported by Daiber (1957). No further trips were scheduled.

DISCUSSION

To obtain sexually mature fish for spawning, the location of the area in which the bulk of spawning activity occurs should be determined. Other investigators have attempted to locate this center. Welsh and Breder (1923) stated that the principle spawning ground in Delaware Bay was on the eastern side between Marice River Cove and Cape May in 3-5 fathoms of water. Harmic (1958) indicated that weakfish spawn predominately in the southwest area of Delaware Bay. It appears that since 1968 major concentrations of large weakfish have occurred near mid-bay during May and June, especially in the vicinity of Brandywine Shoal. Historically, fish taken in this area have been running ripe males and green, running ripe, and spent females which suggests that this area is probably the principle spawning ground for these early run large weakfish in the Delaware Bay.

Several questions arose during the course of the study. These dealt with actual feeding by spawning fish, reliability of information concerning sexual condition, and handling stress.

There is some disagreement as to whether spawning weakfish

feed. Muller (1976) stated that "the reproductive urge must be satisfied before rod and reel catches were reported." In May 1976, the author and Frederick C. Bonner, State of Delaware fishery biologist, took several running ripe females in the vicinity of Brandywine Shoal. Our collections in 1977 took 48 near-ripe females but none that were free running when landed. The question remains that, while weakfish do indeed take bait prior to spawning, how near to spawning can they be caught? Observations on gill net captured, smaller, running ripe females (0.45-2.3 kg) in June 1977 showed that they had been actively feeding just prior to capture; a number of fresh bay anchovy, Anchoa mitchilli, were regurgitated during handling. It is therefore likely that spawning weakfish do feed and can be taken by conventional sportfishing methods.

Information regarding sexual condition of females is often of questionable value for this type of study. Several charter captains (probably the most experienced non-biologists) reported taking ripe females. Upon examination, however, all were several days from spawning.

Some weakfish died in the holding tanks in spite of care taken during capture and handling. This was probably a result of landing time, as all were handled similarly. Those hooked near the surface and landed quickly appeared in somewhat better condition than those taken near the bottom and played for several minutes. Few fish were injured by the lure.

CONCLUSION

Taking ripe weakfish by hook and line for the purpose of artificial propagation is feasible but should not be relied on to the exclusion of other more traditional methods. Although we had no trouble in taking ripe males, we took no running ripe females. The chance of being in the right place at the right time to collect these may be limited to only a few days or even hours, and if the critical period is missed, either because of weather, timing, or mechanical problems, the entire program effort could be lost. To increase the chances of taking ripe females by hook and line, trained personnel should monitor charter boat catches on a two to three day/week basis until the critical period is determined and, then, effort should be maximized.

ACKNOWLEDGEMENTS

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A CASE FOR AN UNDERWATER SLAVE UNIT

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Several authors have described how to take good photos of fish in aquarium tanks (e.g. Axelrod 1970, Meulengracht-Madsen 1973, Thomas 1978). They all recommend strong electronic flashes as light sources, one placed above the tank, and one or two in front.

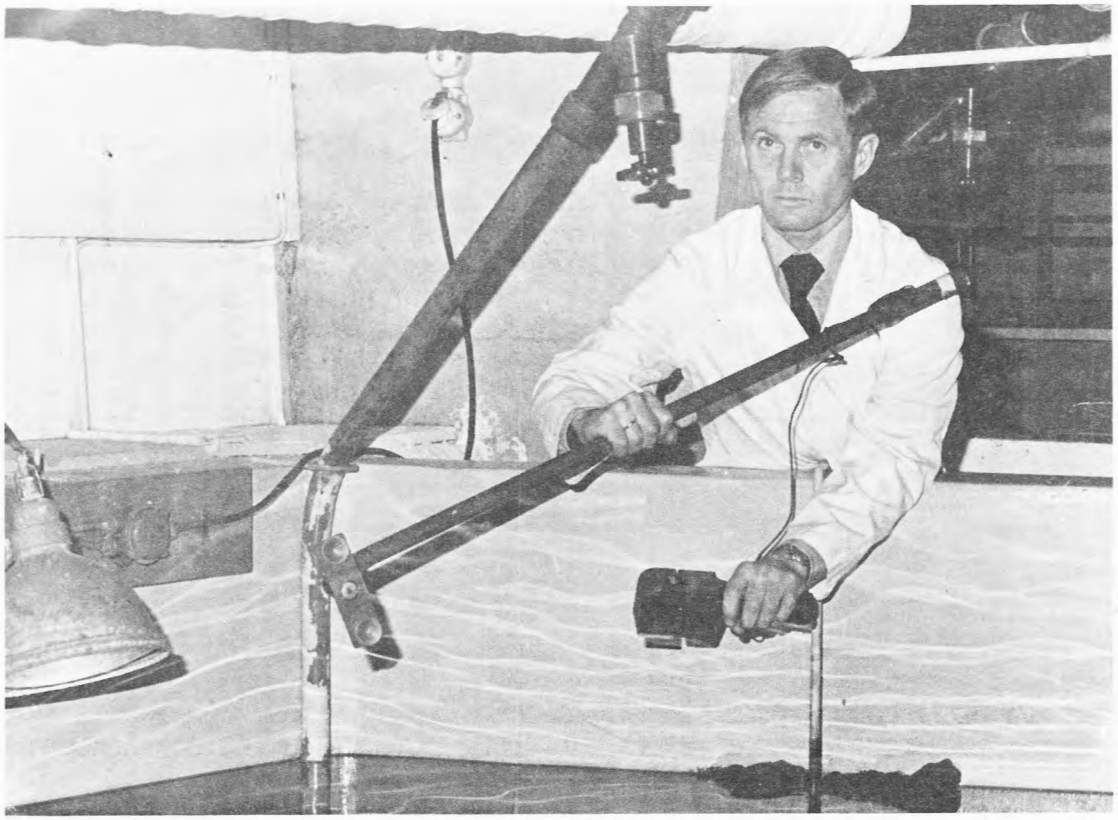
If one uses single phototanks or takes one's shots in a home aquarium, there is no problem to release the strobes simultaneously. Either one uses synchronizing cords or the strobes have built-in slave units. If one wants to take one's photos in a large display tank in a public aquarium, the long distance from the front to the top of the tank or heavy absorption of light in the water may make both methods unsuccessful.

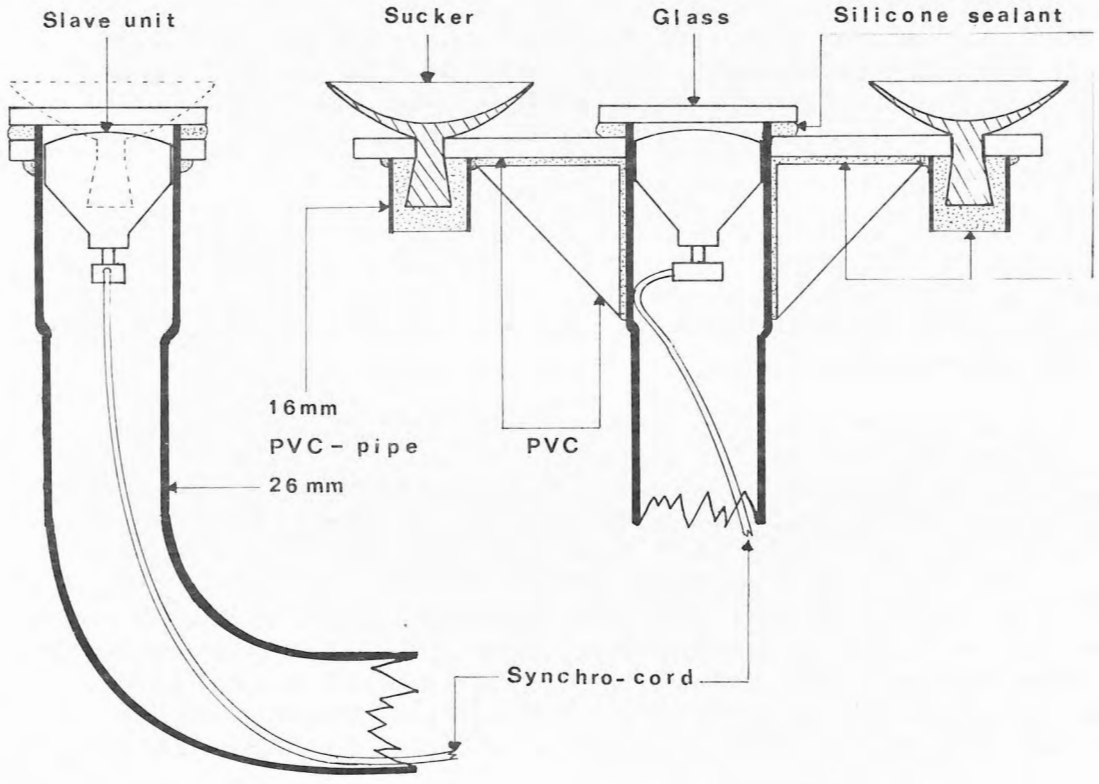
A simple way to set off the top strobe light is, however, to mount a separate slave unit (photocell) in a watertight case and put it into the tank onto the inside of the glass. There are, of course, many ways to make such a case, but the one described here is very simple to build, handy to operate and cheap (Fig. 1).

In addition to the slave unit with an extension synchro-cord, all one needs is PVC pipes (gauge 26 & 16 mm), a sheet of hard PVC (4 mm), a piece of glass (3 mm), two suckers (same type one finds on small aquarium heaters), and a tube of silicone sealant and the primer for PVC.

Start with a 1100 mm long PVC pipe (26 mm) which one bends (heat it with sand inside) in a right angle about 100 mm from the end; at this end make a 40 mm long expansion by heating it and inserting a pipe piece of same gauge. A small slave unit from National (Model PI-3) will now just fit into the opening (Fig. 2). One then makes a hole in the middle of the sucker holder of PVC (140 x 40 mm) for the expanded pipe and also holes for the suckers on each side. The sucker holder supporters are also made of PVC. A 40 x 40 mm piece of glass will cover the opening of the pipe and prop up the sucker holder. Assemble all the parts using silicone sealant as shown in Fig. 2.

The other end of the pipe will stay out of water. However, it is wise to seal it off with silicone in case one drops it into




Slave unit
Sucker
Glass
Silicone sealant
16mm
PVC - pipe
26 mm
PVC
Synchro-cord

the tank by accident. A T-shaped bar upon which one can wind up the excess cord may be glued onto the side of the pipe in the same end.

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Fig. 1. The author with the underwater slave unit for use in public aquarium tanks.

Fig. 2. Longitudinal (left) and cross section of the case.

THEME AND DESIGN IN THE SMALL AQUARIUM

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The public aquarium provides a unique service to any community, whether it is associated with a zoological gardens or whether it stands alone as a separate entity. Its educational and aesthetic value is immense, even if it is composed simply of a group of fish in random aquaria. They can be displayed in an incoherent manner with no planning or forethought as to how to optimize or best utilize the display, educational and research potential of aquatic forms of life.

Conversely, when the entire structure is oriented from the ground up in a specific purposeful direction and its inhabitants carefully selected to represent the achievement of that goal, the public aquarium becomes a living viable part of the community, expressing both man's concern for the world in which he lives and his innate desire to observe and learn the basic biological aspects of the world of water.

In order to best achieve this aim, an appropriate theme must be chosen and followed from the initial planning stages right through to final building completion and opening of the facility to the public. Putting economic considerations aside for the moment, there is one of two fundamental possibilities available to the smaller sized aquarium facility, while a combination of the two becomes a feasible reality only in a much larger structure, such as a giant oceanarium.

On the one hand, a building may be designed to house only two or three rather large tanks, say of 10,000 gallons or greater capacity each, or perhaps a single 100 to 350 thousand gallon tank. In this event, it becomes necessary to adopt a single overriding theme and to exploit it in great detail. Marine aquaria are especially suited to this approach, and individual topics such as Sharks, Whales, Local Reef Fauna, etc., comes to mind.

It might be noted that this concept involves, for the most part, rather large exhibit animals which, because of their size, also will limit their numbers in an aquarium even though large tanks are being used. On the other hand, a small aquarium may choose to adopt a design incorporating perhaps one or two relatively large tanks, supported by a larger number of intermediate and small aquaria, in which may be housed a vast array of both freshwater and marine fauna. This would constitute a multi-theme approach.

In the latter concept, while it is still possible to have only one major all-encompassing theme, it becomes potentially possible for each individual aquarium to express a theme in itself; or perhaps the building can be sectioned to depict groups of aquaria as lesser themes of the major one, e.g.:

1. The world of water with freshwater and saltwater divisions.

2. Around the world with fish with subdivisions depicting various fish of various continents or geographic regions.

3. Regional fish or native fauna, containing only freshwater and/or marine species found locally (areas rich in colorful and diverse species, such as the Florida reefs, frequently adopt such themes.

4. Natural history and Ecology in which behavior and interaction become the themes and the specific species displayed become secondary in importance.

5. Families of fish where taxonomic relationships show a progression from species to species and family to family, the converse of the following theme.

These examples are intended only to indicate the diversity of themes available and need not represent definite proposals.

As the old adage states, "You can please some of the people some of the time, but you can't please all of the people all of the time," we find here that each concept may be of paramount concern to some individual or group in the community. It becomes difficult, therefore, to find an adequate compromise that will satisfy all concerned from their various standpoints.

The multi-theme approach is, I believe, the most desirable solution, as it affords the aquarium its greatest flexibility to meet the requests and desires of the greatest number of people, as well as allowing for unforeseen fluctuations in the availability or desirability of certain exhibition specimens. It also allows for the changing of one or more themes in the future, with only a minimum of disruption and thus, special conditions and considerations may be met on either a temporary or permanent basis as required.

To appraoch a multi-theme concept in the design and planning stages of the aquarium is really to address oneself as to how best achieve the most flexible and versatile aquarium system possible. Once decisions have been reached regarding the number, size and arrangement of tanks to be included, all materials and life support systems to be used in the construction and

maintenance of the facility should be selected as though the entire system were to be fully delegated to saltwater usage.

The only remaining item left for future considerations for freshwater usage is to pipe freshwater to all of the same points where there are saltwater lines and taps. This would require a dual water system to each aquarium in the building but would allow a tank to become either a freshwater or saltwater exhibit since the corrosive properties of saltwater would be accounted for in the initial selection of the construction materials and life support systems. Any construction material that will work in saltwater will work in freshwater, except with a longer operating life.

The range and diversity of aquatic life is so extensive that the only limitations to the number of topics that can be shown lies in the actual number of tanks available for display purposes and in the imagination and skill of the persons presenting those themes. It might not be possible to obtain a referendum vote from the community regarding which species or topics they would most prefer to see in an aquarium before it is opened. This can, however, be accomplished through informal surveys and a willingness to listen to suggestions from visitors to the aquarium after it is opened. It would only be appropriate to respond to and seriously consider proposals from people who supported the aquarium with their attendance, rather than those who might wish to have certain themes presented, but who would never visit the facility to see the exhibits.

It is possible from the experiences of other existing aquaria to establish some general guidelines as to what is most attractive to most people. A balance of about 60-70% marine tanks, with the remaining 30-40% being freshwater, would be a good starting point. People are most likely to be attracted to and favorably impressed by exhibits which represent the most bizzarre, dangerous, strange, unusual, rare or endangered species it is possible to obtain. They wish to see things that they have heard about through the media of books, movies and TV, and which they have at least some vague or imagined notions about.

Although the species and topics which can be sought initially are the following, they are by no means a complete listing but merely represent food for thought:

1. A Central Reef - This would be the central focus of the aquarium, the most brilliant, largest and spectacular exhibit in the aquarium, e.g., the flower gardens of offshore Texas or a representative Caribbean reef setting. The flower gardens could also serve to represent native

species which are seldom seen by local residents.

2. Man-Eating Fish - The Piranha is one of the most popular of exhibits, and even though they may be a shy group in captivity and easily intimidated by their tankmates, they are nonetheless regarded by aquarium visitors as one of the most fearsome of all fish.

3. Seahorses - In additon to the male being the one to bear young, there are a surprising number of other traits which are possessed by no other species and which make this animal one of the most unique of all fish. The Texas coast (along with Florida) is the habitat of a dwarf species which when fully adult at 3/4", makes it one of the smallest fish in the world.

4. Electrical Fish - From the Electric Eel, which can generate up to 650 volts and is the most powerful of all electricity-generating animals, all the way down to the Pelagic Shark, which generate micro-volts, many species of fish have electric organs which can be demonstrated in an aquarium with audio-visual aids such as oscilloscopes and amplified sound systems, so that people can see and hear what could otherwise only be felt.

5. Primitive fish, such as the Sturgeon and Paddlefish, make exciting exhibits not only because of their size, but also because of their bizarre appearance.

6. Air breathing fish, such as the Lung Fish are fascinating exhibits because of their evolutionary significance, even though the animal itself may only move every hour or so to surface and take a breath of air. More of scientific or educational appeal than a layman's delight, there are no more than two or three aquaria in the nation which have each of the South American, African and Australian varieties.

7. Shark displays, while usually associated with the larger, more spectacular varities, may also enhance the smaller aquarium, too. There are a number of small (2-3 feet) species which are often times brightly marked, i.e., Chain Dogfish, Zebra Shark, Wobegong, Carpet Sharks, Leopard Sharks, etc.

8. Giant Octopus and Giant Lobster - While requiring special life support system considerations, they are very impressive to most people and interesting to observe.

9. Invertebrates - While no mention has heretofore been made

regarding them, they constitute as wide or wider a diversity of forms as fish and should be an integral part of the aquarium, whether housed in the same tanks with fish or as separate outstanding exhibits in themselves.

10. Venomous Fish - Lionfish, Stonefish, etc.

11. Bizarre Appearing Fish - Angler Fish, The Atlantic Batfish, etc.

12. Popular Food and Game Fish - Trout, Bass, etc.

13. Camouflage in fish.

14. Mimicry - South American Leafish.

15. Unusual Food Gathering Methods - Archer Fish.

16. Pollution - Two identical tanks, one with life forms, the other with garbage only.

A REVIEW OF LARVAL FISH REARING TECHNIQUES USED IN OBTAINING A LARVAL SERIES FOR DESCRIPTIVE PURPOSES

THE SEATTLE AQUARIUM TECHNICAL REPORT NO. 2

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INTRODUCTION

Larval fish rearing techniques have been employed mainly for aquaculture or life history descriptive purposes. The work reviewed in this paper and on-going research at The Seattle Aquarium are orientated toward producing a larval series. A larval series is of value in providing taxonomic and life history information and in providing baseline information for fisheries management. Some techniques in aquaculture are applicable, but much is species specialized and large scale.

First, a review of the documented rearing studies is presented along with considerations of rearing success. The techniques described here are those which have been successful in rearing species past metamorphosis. Next, the rearing techniques used at The Seattle Aquarium are described. Those aspects considered are the physical setup of tanks, lighting, water quality, handling of eggs and feeding of larvae.

DOCUMENTED REARING STUDIES

HANDLING OF EGGS

Eggs for rearing larvae have been obtained in several ways. They have been spawned artificially, separated from plankton samples or other net samples, collected intertidally, or obtained from adults which have spawned in aquaria (Barnabe, 1973; Marliave, 1976a). Eggs collected in the field were transported in oxygenated and temperature-regulated seawater (Marliave, 1976a). Eggs were then added directly to rearing containers.

Pelagic eggs have been allowed to float free in rearing tanks (Barnabe, 1973). The water in these tanks was kept motionless to avoid damage to the eggs (Barnabe, 1973; Hunter and Thomas, 1973). Marliave (1977a) incubated intertidal or shallow water demersal eggs in flowing seawater (0.31/cm^2/min.). In one study, seawater had been millepore filtered to provide a bacteria-free

incubation medium (Fishelson, 1976). Dead eggs have often been removed to reduce the chance of bacterial and fungal growth (Ryland and Nichols, 1975).

PHYSICAL SETUP

The wide range of successful rearing tanks have included: 5-25 liter glass jars (Fugita and Uchida in May, 1971; Molander and Moland-Swedmark in May, 1971; Qasim in May, 1971); plastic wading pools of 320-570 liters (Delmonte, Rubinoff and Rubinoff, in May, 1971; Hunter, 1975); and tanks of about 2,000 liters (Jones, Alderson and Howell, 1973; Marliave, 1976b, 1977b). Space requirements have varied for the different species being reared. Ehrlicht and Farris (1972) found that tank size may have influenced growth patterns. Young larvae grew faster in small containers than in large containers. Older larvae grew faster in large containers. A good growth rate in small tanks may be due to food concentration, whereas a larger tank may provide the advantage of unrestricted movement (Blaxter, 1962; Ehrlicht and Farris, 1972). Larvae vary in their sensitivity to contact with tank walls and, therefore, larger sized tanks may be required for successful rearing of some species (Jones et al, 1973). The demersal or pelagic nature and behavior of the larvae should determine these needs. Also related to the size of the tank has been the density of the larvae. Since the goal of such rearing has not been aquaculture related, the number of larvae needed will be relatively small. Recommended density for rearing has been 10 eggs/L for short-term experiments, and 15 eggs/L for long-term experiments (Hunter, 1975). A density of 30 eggs/L yielded slower growth and lower survival (Hunter, 1975). According to Hunter (1975), a greater horizontal area (without an increase in volume) will support a more dense larval population. It would also be advisable to rear only one species in a tank since some larvae are highly piscivorous (Hunter, 1975; May, 1970).

Many glass aquaria have been used for rearing (Saksena and Richards, 1975; Shelbourne, 1964, May, 1971). However, black walled tanks have been preferred. The larvae may be startled by movements outside of a glass aquaria, and many marine larvae are photopositive and would, therefore, collide with the glass at reflective points (Hunter, 1975; Marliave, 1976a; Walker, 1978). Also black may provide a contrasting background for the larvae to distinguish their food (Blaxter, 1962). The rectangular shape of glass tanks has also been shown to be disadvantageous (Marliave, personal communication). For many larvae, especially pelagic species, a circular tank with peripheral water flow has been ideal. A peripheral water flow discouraged larvae from entering the area near the tank walls. This kept

collisions with the tank wall to a minimum.

Circular tanks have been made of plywood with plastic liners (Barnabe, 1973), fiberglass, and plywood with fiberglass lining (Marliave, 1976a).

Tanks with a flow-through system required large surface area drains placed near the bottom; the incoming water positioned to create the proper currents; and the flow and current low enough to not disrupt normal activity of the larvae or carry food out the drain too quickly (Marliave, 1976a, 1977c). In one study, the drain outlet was placed at the surface to take off surface scum (Jones, et, 1973). In another study, the same problem was minimized by placing polyethylene covers over the tanks (Ehrlich and Farris, 1972).

ENVIRONMENT

Natural substrates have not usually been used in rearing tanks. Delicate larvae may become trapped or damaged in substrate surfaces. Marliave (1977c) proposed that, in certain species, suitable substrate surfaces were an important aspect of reducing extensive mortalities at settlemnt. Marliave studied substrate settlement of Xiphister atropurpureus and Gobiesox maeandricus. For Gobiesox maeandricus, settlement was first on plants and then on rocks (Marliave, 1977c).

Photoperiods have been important to larval survival. The sources of lighting used in studies reviewed were all artificial and usually fluorescent (Ehrlicht and Farris, 1972; Jones, 1972; Jones, et al, 1973; Saksena and Richards, 1975). Intensities were usually near 500 lux at the surface for daylight, 0 for dark and 10 lux for moonlight (Hunter and Sanchez, 1976; Jones, 1972; Marliave, 1977b). Some researchers used twelve-hour photoperiods (Hunter and Sanchez, 1976; Marliave, 1977b), but most felt that constant illumination was advisable. Jones (1972) felt that dark periods may have been responsible for mortalities in larval turbot. Ehrlicht and Farris (1972) used continuous lighting so as to avoid unnecessary shock to the fish. Since most larvae fed in the daytime (Marliave, 1977c; May, 1970), constant illumination allowed the larvae to feed continuously (Marliave, 1976a; Saksena and Richards, 1975; Walker, 1978). In a comparison of rearing with a light/dark regime, continuous light, and a regime with simulated twilight periods, Marliave (1977b) found that the light/dark regime had a poorer survival rate than the other two.

WATER QUALITY

The first consideration for maintenance of water quality is

whether tank design entails a flow-through or a closed system. The main prerequisite and limitation to a flow-through design is that the facility must be near a source of seawater of adequate quality or where filtration and treatment is feasible. Marliave (1977a) in his research at Bamfield Marine Station (B.C., Canada) had success using unfiltered water from a depth of 21m. Unfiltered water may provide organisms that would be a supplemental food source. Studies showing the advantages of unfiltered water have not been done. Most open systems involved the use of filtered seawater, minimally sand filtered (Jones et al, 1973; Marliave, personal communication; Shelbourne, 1964). Some studies have augmented the use of sand filters with further processes such as the use of millepor filters (Fishelson, 1976) and treatment with ultraviolet light (Hunter, 1975). One setup for UV treatment used a 30 watt UV lamp with the water siphoned through a water jacket surrounding the bulb (Ehrlicht and Farris, 1972). According to Hunter (1975), open systems are advantageous if there is an easily obtainable food and the larvae are strong swimmers.

Closed systems in contrast have the advantage that neither the food organisms nor the larvae will be swept out the drain (Hunter, 1975). A closed system allows the rearing of exotic species which could not tolerate the conditions present in local seawater. Also, a closed system enables inland labs to rear larvae. Many closed systems have been successful (Barnabe, 1974; Ehrlicht and Farris, 1972; Hunter and Thomas, 1973; Jones et al, 1973; Ryland and Nichols, 1975; Shelbourne, 1963). In all closed systems, partial periodic water changes were made unless the duration of the experiment was short. A closed system often involved maintaining static seawater (Barnabe, 1974; Ehrlicht and Farris, 1972; Hunter and Thomas, 1973). This reduced the risk of pelagic eggs or larvae contacting the sides of the tank. Also, a closed system made possible the use of antibiotics to control bacteria (Ryland and Nichols, 1975; Shelbourne, 1963). In all rearing attempts, dead larvae were removed. This is necessary for both water quality and mortality determinations. Also, detritus may contribute to mortalities (Jones et al, 1973). Marliave (personal communication) siphon-cleaned the bottoms of his tanks.

Other considerations of water quality are salinity, aeration and temperature. Salinities were not regulated in any of the studies, but salinity values were often recorded (May, 1971). Aeration was necessary only in closed system tanks. Those studies which used static water had no aeration. Hunter (1975) found that aeration was not usually essential and that excess aeration can cause damage to the larvae. A low level of aeration had the advantage of breaking up dense food patches and

seemed to help in maintaining stable temperatures (Hunter, 1975).

The optimal temperature in a rearing tank was felt to be the normal thermal range of spawning for the species being reared (Hunter, 1975). Temperature control methods include: air conditioned rooms (Hunter and Thomas, 1977); seawater ice added to tanks (Marliave, personal communication); and insulating water baths (Shelbourne, 1963; Ryland and Nichols, 1975).

FOOD

Proper food is obviously very important to the survival of larval fish. Inadequate food slows growth and causes mortality (Hunter, 1975). Aspects of feeding that must necessarily be considered are the type of food, whether a particular food item is obtainable in proper quantities, its nutritional value and its size. For most of the foods used in rearing attempts, any one particular food item has resulted in both success and failure for different studies. These variations in success may be due to the differing needs of different species. A food which is not proper for one species may be ideal for another. Some foods, however, may be improper in some aspects for all fish. Food item lists in the literature have included all types attempted. It would seem more advisable to consider only those items which have led to successful rearing. Table 1 contains a list of those food types that have met with success and the studies for which they were used.

Types of food are those either commercially available, cultured, or collected from marine waters. The ideal choices are those which are commercial or cultured. Collecting food is time consuming and somewhat unreliable. The advantage of collected food is that it may be nutritionally close to that of natural food. Commercial foods are not very commonly used in rearing larvae other than those used in aquaculture. Those commercial foods used have been ones that were developed for aquaculture. Commercial foods are usually nonmotile , and the larva may not be able to see the particles (Fishelson, 1963). Dry food is not advisable for closed systems because it causes fouling of the water (Delmonte et al in May, 1971; May, 1970). Cultured foods have been the major source used. They may be cultured in the rearing tank, but were most usually cultured separately (see Table 1). Some food organisms, although cultured separately, are fed on an algae that has been cultured in the rearing tank. The food organism is thus maintained in better condition (Hunter, 1975). The ingested algae may also be of nutritional value to the larvae (Jones et al, 1973). Tanks containing rotifers or Artemia nauplii have been innoculated with Dunaliella, Tetraselmia, Nannochloris and Chlorella algaes (Hunter,

1975; Jones et al, 1973).

Often a species of larvae has been raised on several food types. Either mixed food types have been used or different food types were added at appropriate stages of larval develpment. Larvae have different nutritional needs at different periods of development. This is most evident with regard to ideal prey size which varies with the growth of the larvae. The nutritional value of some foods may also be a problem. Mixing foods possibly covers a broader range of nutritional needs. The biggest debate has been over the adequacy of Artemia nauplii. Many workers have not fed Artemia nauplii alone (Barnabe, 1974; Hunter, 1975; May, 1970). This food has, however, been used solely for rearing turbot after day 12-14 through metamorphosis (Jones et al, 1973). Hunter (1975) felt that only larvae with differentiated guts should be fed Artemia because it is resistant to digestion. Larvae with straight tube digestive tracts should be fed other foods (Rosenthal, 1969). Also, digestive problems may be caused by the ingestion of Artemia egg shells introduced with the nauplii (Morris, 1956 in May, 1971).

Artemia nauplii are often too large for early stages of certain larvae to ingest. San Francisco brine shrimp eggs are the preferred type because they produce the smallest nauplii (Hunter, 1975). Hunter (1975) has proposed a size calculation for optimal prey width. Prey width should equal 1/4 to 1/3 the mouth opening for young larvae. After two days, prey width should be 1/2-2/3 the mouth opening. Mouth opening value is calculated by taking the lengths of the lower and upper jaws and using the Pythagorean theorum (assuming a 90 degree jaw angle). Mouth opening must be recalculated as the larvae grow.

It has also been generally agreed that food density must vary with larval age. The food density requirement is higher during the first few days after yolk sac absorption than at any other time (Hunter, 1972; O'Connel and Raymond, 1970: Riley, 1966; May, 1970; Hunter, 1975). This higher food density requirement is probably due to a lower search and strike success level during the first few days of feeding (Hunter, 1972). After this first stage, too high a food level may be detrimental. A high food level can foul the water and promote growth of bacteria and ciliates (Riley, 1966). It may also cause death of larvae from overfeeding (Hunter, 1975). Many larvae do not seem to have a satiation mechanism (Hunter, 1972). Density of the food should be based on size of the tank, water system and flow, density of larvae, and age and behavior of the larvae. Marliave (1977a) fed larvae to excess, but in a large tank with an open system. Some cultured foods form patches in the rearing tank. G. splendens and Artemia nauplii form surface patches (Hunter and Thomas, 1974). Also lights have been used to aggregate patches of food in a particular spot (Hunter and Thomas, 1974).

Table 1. Food items and their methods of acquisition which have been used successfully in rearing in the studies listed.

FOOD ITEM	HOW OBTAINED	STUDIES WHERE USED
planktonic green algae	cultured with larvae	Sylvester, et al, 1975
Brachionus plicatilis (rotifer)	cultured separately	Hunter & Thomas, 1974 Barnabe, 1973 Jones, et al, 1974 Mito, et al. 1969 in May, 1971 Okamoto, 1969
Fabrea salina (ciliate)	cultured separately	Barnabe, 1974
Artemia salina nauplii wild plankton	cultured/hauled	Barnabe, 1974 Blaxter, 1968 in May, 1971 Marliave, 1976a & 1977a,b Saksena & Richards, 1975
Artemia salina nauplii (alone)	cultured separately	Barnabe, 1974 Delmonte, et al, 1968, in May, 1971 Ehrlicht and Farris, 1972 Jones, et al, 1974
Artemia nauplii and adults	cultured separately	Ehrlicht & Farris, 1972
wild plankton	comes in flowthrough tanks	Bardach, 1968 in May, 1971 Blaxter, 1969 in May, 1971 Jones, et al, 1974
wild plankton - strained & unstrained	hauls	Blaxter, 1968 & 1969 in May 1971 Marliave, 1976a, & 1977a,b Mito, et al, 1969, in May, 1971 Sakagawa and Kimura, 1976 Saksena and Richard, 1975

rotifers	cultured	Barnabe, 1974
commercial trout food	commercial	Sakagawa & Kimura, 1976
larvae of bivalve mollusks	cultured	Hirano, 1969 Loosanoff & Davis, 1963 Morris, 1956, in May, 1971 Okamoto, 1969
Gymnodinium splendens (phytoplankter dinoflagellate)	cultured separately and in tank	Hunter & Thomas, 1974 Lasker, 1975
Blanus nauplii (barnacle) wild plankton	not mentioned	Blaxter, 1968, in May, 1971
commercial fish fry food	commercial	Delmonte, et al, 1968, in May, 1971
boiled egg yolk or powdered egg	commercial	Fishelson, 1963 Fujita, 1966, in May, 1971 Heuts, 1947, in May, 1971
Coscinodiscus concinnus	not mentioned	Hertling, 1932, in May, 1971
Biddulphia mobilensis	not mentioned	Ibid. 1932
Copepods	haul & cultured	Ibid. 1932 Kotthaus. 1939
Tigriopus sp.	haul & cultured	Blaxter, 1968, in May, 1971 Fahey, 1964 Morris, 1956, in May, 1971

THE SEATTLE AQUARIUM REARING STUDIES

Hatching and rearing of indigenous marine species is a major research emphasis at The Seattle Aquarium. A larval laboratory was designed and set up during 1977 and 1978. Successful rearing has been done with the larvae of Gobiesox maeandricus, Eumicrotremus orbis, Anarrhichthys ocellatus, Aulorhynchus flavidus and Nautichthys oculofasciatus. Three other species have been reared for periods past one to three months, but not through metamorphosis. The Washington State Department of Fisheries has long had a salmon enhancement program with much financial support. The Department of Fisheries has recently created a similar marine fish enhancement program. Future plans for enhancement will first concentrate on lingcod (Ophiadon elongatus), rockfish (Scorpeanidae) and flatfish (Pleuronectidae) with Pacific halibut (Hippoglossus stenolepis) as the major emphasis. The Seattle Aquarium will be working with the Department of Fisheries on hatching and rearing lingcod as a method of enhancement.

The Seattle Aquarium has been involved with rearing of marine fish for larval species identification and morphological development purposes. Past rearing on non-commercial species has been for the purpose of identification and early life history information. Such information is needed for baseline descriptions now being done by various state and federal agencies. Our setup has been designed primarily for rearing species of marine fish which have demersal eggs.

EGGS

Eggs have been obtained from display tanks and in the field. Rearing larvae from field-collected eggs can be disadvantageous if they are unidentified and few in number. Rearing of field-collected eggs has been less successful primarily because mortalities have exhausted their numbers prior to the larvae reaching metamorphosis.

Eggs spawned in display tanks are not removed if they are strongly adhesive or if parental care exists. Other demersal eggs are placed in aquaria in fine mesh nets. A strong current is maintained through the nets to provide proper circulation and aeration. Some eggs have been incubated in the rearing tanks. This technique creates difficulty in establishment of a concise age group for a larval series. After hatching, the larvae are moved to the rearing tank by pipet. We have found that larvae vary in their temperature change tolerance. If larvae are hatched in high turnover (colder) incubation tanks, care must be taken to acclimate them to the low turnover (warmer) rearing tanks.

TANKS

Three types of rearing tanks are used in the larval rearing laboratory at The Seattle Aquarium. These are two rectangular tanks of approximately 200 liters each, one circular fiberglass tank of 1,000 liters and three hexagonal 1,000 liter tanks constructed of plywood and fiberglass (see Fig. 1a and 1b, and Fig. 2). Hexagonal tanks function as if circular but are easily and economically constructed. After construction with the wood, they are fiberglassed and then painted with a flat black fish-oil base, non-toxic Rustoleum paint (Fig. 2). Small glass aquaria are used for rearing juvenile fish which are well past metamorphosis.

Water is supplied to each tank on a flow-through basis. Vertical inlet pipes have been drilled with a series of small holes and positioned such that a circular flow is achieved in all the tanks (Fig. 1a and 1b). The drainpipes were fitted with fine mesh screens and positioned three inches off the bottom in the center of each tank. The water level is maintained by exterior overflow pipes. Cleaning is done by siphon. After the level of water has been lowered by siphoning, the flow may be shut off and the drain cover screen removed and cleaned without losing larvae.

WATER QUALITY

Water in the tanks comes from Elliott Bay, Washington, at a depth of 12 meters. This water passes through gravity flow sand and gravel filters. For a period of three hours each night, however, filters are shut down and unfiltered water passes through the tanks.

Salinities are lower than that of the ocean because of extensive freshwater runoff into Puget Sound. Salinity is approximately 26 ppt. No aeration is provided in the tanks. Temperature was low at the time of year when early larval development was occurring but increased with warmer weather. Higher summer temperatures may have been responsible for increased mortalities in Eumicrotremis orbis. The more intertidally occuring Gobiesox maeandricus has shown no such effect. Some temperature moderation can be achieved by increasing the flow of water.

ENVIRONMENT

The interiors of the tanks are non-reflective black. Drain pipes also are black and inlet pipes are either black or gray. Plexiglas borders are placed around the edges of the tank to shade the walls. These shades tend to repel photopositive

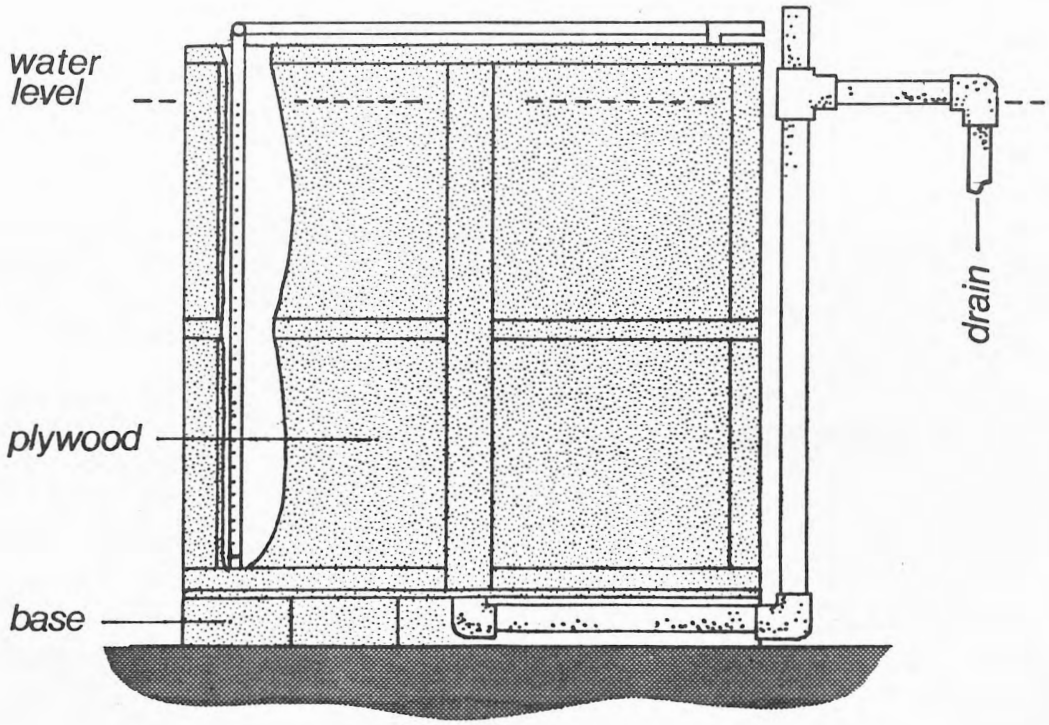
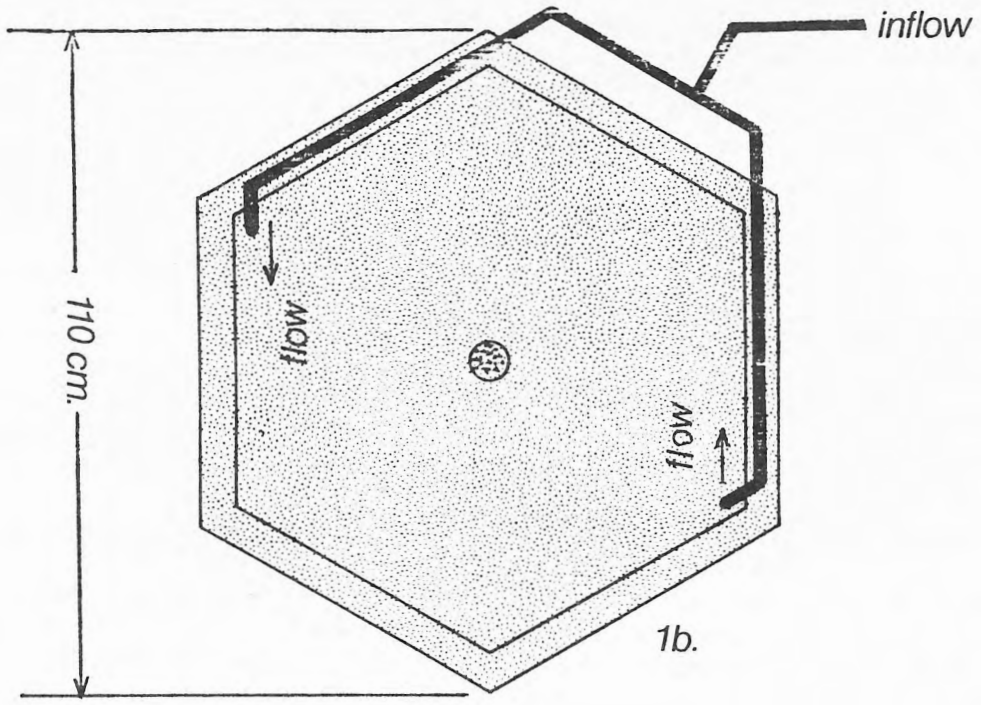


FIG. 1a.



1b.

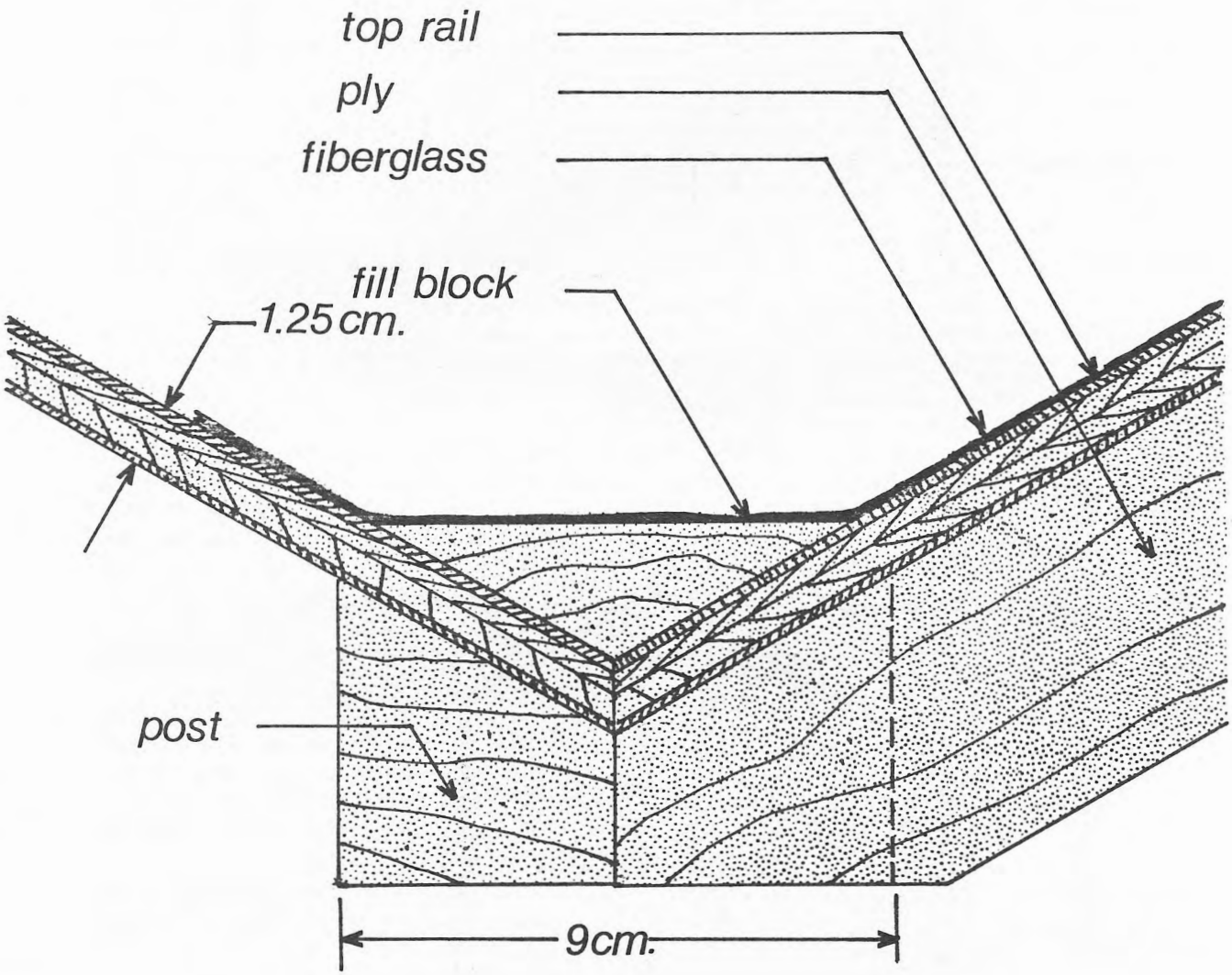


FIG. 2

larvae from the tank walls. Photo periods have not been attempted. Constant illumination is provided by fluorescent bulbs. The illumination intensity at the water surface has not been determined.

There has been no attempt to provide any natural substrate. We have not found any appreciable mortalities at settlement for those species reared past metamorphosis. The surface of the tank interior appears to be adequate for attachment of Eumicrotremus orbis and post-metamorphosis Gobiesox maeandricus.

FOOD

Artemia nauplii were the initial food source for all larvae reared. After the Artemia eggs were incubated for 48 hours, the eggshells were allowed to float to the water surface in the culturing tank. The nauplii were then attracted to a light in a lower portion of the tank and siphoned out. This technique greatly reduced the amount of eggshells that were introduced into the larval tanks. The nauplii were added to the tank daily. The nauplii formed a patch in the center surface of the rearing tanks. This patch often remained present until the next feeding. The larvae also may have fed on natural plankton which entered with the unfiltered water. As larvae became able to feed on larger organisms, adult brine shrimp were added to the tanks.

1978-79 RESEARCH GOALS

The emphasis planned for the 1978-79 period will be the rearing of lingcod and several non-commercial species. Rearing of lingcod will be aimed towards examination of aquaculture feasibility. Further emphasis on early life history description is planned for a few other marine species. A quantification of light, temperature and natural plankton will be made. Comparisons of the effects of food types on growth rates are planned.

ACKNOWLEDGMENTS

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A MYXOSPORIDIAN, HENNEGUYA SP., INFECTING THE PERMIT, TRACHINOTUS FALCATUS

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Miami Seaquarium
Miami, Florida

Of the thirty thousand known species of Protozoans, those of the Myxosporidea have evolved parasitic to fishes in nature, in commercial fisheries, and in the aquarium. (1) Myxosporidians are members of the subphylum Cnidospora which includes the class Microsporidea, also responsible for numerous diseases of fishes. (2) Identification and treatment of Myxosporidian infections is difficult since pertinent literature on the subject often is unconclusive and in some cases non-existent. In addition, diagnosis is easily confused with the more common aquarium diseases.

The infection on the Trachinotus falcatus was first observed on September 13, 1977 in a 1,900 liter open system exhibit at the Miami Seaquarium. The specimens developed opaque white nodules approximately 2.5mm x 1.0mm along the lower edge of the operacula, between dorsal rays, and on the body at the base of the pectoral fins. Besides the eight small Permit in the tank, there were also five Southern Flounders (Paralichthys lethostigma), one Lookdown (Selene vomer), and a Pompano (Trachinotus carolinus). Yet, aside from the Permit, no other species had similar symptoms of external encystments.

A systematic parasite treatment was initiated immediately to destroy any free-swimming or water-borne organisms, and to penetrate the cysts at concentrations not toxic to the fish. The diseased fish were not moved since all other specimens in the tank were possibly carrying the disease. The treatment consisted of chlorine dioxide at .5 ppm for 48 hours. The system was then opened and a copper concentration of about .15 ppm was maintained. In addition, following the chlorine dioxide treatment, daily copper-formalin baths lasting 20-30 minutes were given for the next three days. This treatment consisted of copper concentrations of about .30 ppm and 1 ml/gal stock 37% formalin.

On September 20th, a specimen was netted from the tank and anesthetized with MS-222. Cysts were clipped from the soft dorsal and a scraping was taken from the operculum. There was no resulting loss of health from the imposed stress on the fish and the removal of the diseased tissue seemed to accelerate its recovery. The samples were taken to the Rosenstiel School of

Marine and Atmospheric Science of the University of Miami and microscopically examined by Dr. Edwin S. Iversen. The causative organism was identified as a Myxosporidian of the genus Henneguya.

Myxosporidians are classified according to the shape of the spore as well as the morphological structures, the most obvious being the polar capsules containing filaments believed to be the organelles for attachment to the host. (3) The genus Henneguya is characterized by two polar capsules with the spore body compressed along the sutural plane, usually with an iodinophilous vacuole and caudal extensions of each valve. (4)

The life cycle begins with the water-borne spore attaching to the host substrate. Upon contact with the host, the polar capsules open for attachment of the filaments, and the plasmodium is released. (5) The plasmodium or sporoplasm migrates to the specific host tissue where it develops as a feeding trophozoite through saprozoic absorption. (6) At this point, the mature trophozoite undergoes multiple asexual fission (schizogony), to form a syncytium. This is merely a mass of protoplasm containing many nuclei not separated by a cell membrane. (7) In this syncytium the cells specialize to form the mature spore, thus completing the life cycle. (8)

The genus Henneguya has several species of world-wide distribution. In the waters around Florida where this particular species was found, H. ocellata has been described from the Red Drum (Scienops ocellata), (Iversen and Yokel, 1963); H. lagodon has also been described from another common local fish, the Pinfish (Lagodon rhomboides), (Hall and Iversen, 1967). (9) More recently, Sindermann (1977) described Henneguya sp. causing cardiac myxosporidosis in the Pompano, (Trachinotus carolinus), a close relative to T. falcatus. (10) At the time of this writing, the species of Henneguya found infecting the skin and fins of Permit remains undetermined, not withstanding the possibility of it belonging to a new species.

Acknowledgment

Dr. Edwin S. Iversen of the Rosenstiel School of Marine and Atmospheric Science identified the genus of the Myxosporidian from the samples taken and provided much information concerning this group of protozoans.

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AIR LIFTS EXAMINED IN DEPTH
OR
HOW TO ACCOMPLISH AMAZING FEATS WITH MODIFIED WATER

George Henkel
(A Novice Amateur Aquarist)

Having been immersed (embroiled) in a controversy over how the ubiquitous air lift water moving device operates, it seems reasonable that I should share my newly acquired knowledge with other interested parties.

Oh, yes. I had read all the books by experts. Who else writes but experts (and dummies like me)? Right? Right. Of course some experts write in more depth than others. Some just skim over the surface when the going gets a little sticky.

Not only have I read a number of books, but I have heard an even greater number of arguments. Most writers agree that you just inject some air into the bottom of a tube of water and presto, the water rises in the tube. These people, the shrewd ones, just leave it there and pass on to other important and less controversial considerations. Bully for them. No hassle there.

Others, the more erudite and more daring ones, press on to enlighten us further. And my, oh my! Do I need enlightenment. "Look, you dummy," they tell me, "why get complicated? Anybody can plainly see that when you mix air and water, the result is a lighter mixture, so it rises in the tube." The sardonic laughter echoes in my ears, along with the squeaking of the chalk, as my tutors rapidly cover the blackboard with diagrams and pictures of water and bubbles. Alas, all of this leaves me (apparently stubbornly) unmoved. "No," I protest, "I don't see the validity of your argument and logic."

"Why not?" they persist. "Don't you agree that the mixture of air and water is lighter than water alone?"

"Well, yes," I respond weakly, "but..." And my words are lost in the chuckles of amusement over my stupidity.

Sooo, I leave. I go home and mull; something I do quite well since it requires no effort. Aha, I have it! I go back to my scholarly friends, so eager to share their knowledge with me. How I admire their patience with someone so dull and adamant in his blissful ignorance.

"Now," I start out bravely, "suppose we put a little cover over each air bubble so we can contain them and manipulate them."

"And how do you propose to do that?" they ask with annoyance at this absurdity.

"It's easy," I assure them. "You just go to the sporting goods store and buy some ready-made bubbles; also known as table tennis balls." Blank stares.

"Any how, you get a supply and in your extra tank you dip your arm in and pop some balls into the bottom of a suitably sized vertical tube. As the piboa (plastic isolated bubbles of air - scientific nomenclature, you see) rise in the tube, they carry water along with them."

"Well?"

"That's it! Don't you see? The bubbles in rising carry water along with them. If you could keep the piboa coming continually into the bottom of the tube, you would be pumping water."

"That doesn't prove anything." they tell me. "It still looks like a simple case of the air/water mixture being lighter than water alone."

I withdraw again. I mull some more. And then I come back with this. "Let us put a net over the top of the tube. As the piboa rise in the tube, water will be forced out of the tube as before. Only this time it escapes through a net that holds back the piboa."

"So?"

"Well, when the tube is full of piboa, there will be no more motion of them toward the top of the tube. At that point, although the mixture of piboa (bubbles) and water is "lighter", as you claim, there will not be any further motion of water. Now, if you would just find me a net."

Inexplicably, my listeners quite suddenly realized they had important business elsewhere. One had to feed the animals. Another had to make a very important and overdue telephone call, and the last is still presumably looking for a net.

The sudden loss of my audience left me with no alternative to going home and gnashing my teeth. Right to the climax, and I lose my listeners. Drat! Well, never mind. I can always

mull some more. And I did just that.

In my mind I carried my proposed experiments just a little bit further. I lowered the tube a bit deeper into the water until its top was a bit below the surface, but with the other end clear of the bottom.

Now, if I put stones or marbles into the tube, the mixture will be heavier. Therefore, the water will flow downward in the tube, around the stones or marbles. Now there is an idea that may have some possibilities. Perhaps I was wrong. Let's see. I could sell clear plastic tubes filled with colorful marbles to the aquarium fanciers who want the water to go downward and tubes filled with pretty table tennis balls to those who want the water to rise.

No more air pumps humming away. No more flexible tubing or valves. Just a handsome plastic pipe or tube filled with marbles or balls to make the water gush down or up around them, depending on whether the mixture is heavier or lighter. I can see it now. A real bonanza. Perhaps I should call my patent attorney before some of you people out there get ideas that will deprive me of the just reward of my mulling.

But what about that net that someone was going to obtain for me. As a matter of fact, right at this moment, a couple of determined looking characters are cautiously approaching. One has a rather oversized net. The other is carrying a rather strange looking coat with long sleeves. I wonder if he knows that its belt is dangling. Well, I must go and see what they want. In the meantime you will just have to get your own piboa, your own net, and do your own mulling.

And you can just forget about that ridiculous idea that the water in an air lift rises because it is carried along with the rising bubbles. See for yourself, as I was about to do. Put some stones in a plastic pipe and watch it suck the water down when you immerse it in your tank, or spend a few bucks for table tennis balls and stand back as you enjoy the sight of water squirting out the top of the plastic pipe in which the mixture is "lighter".

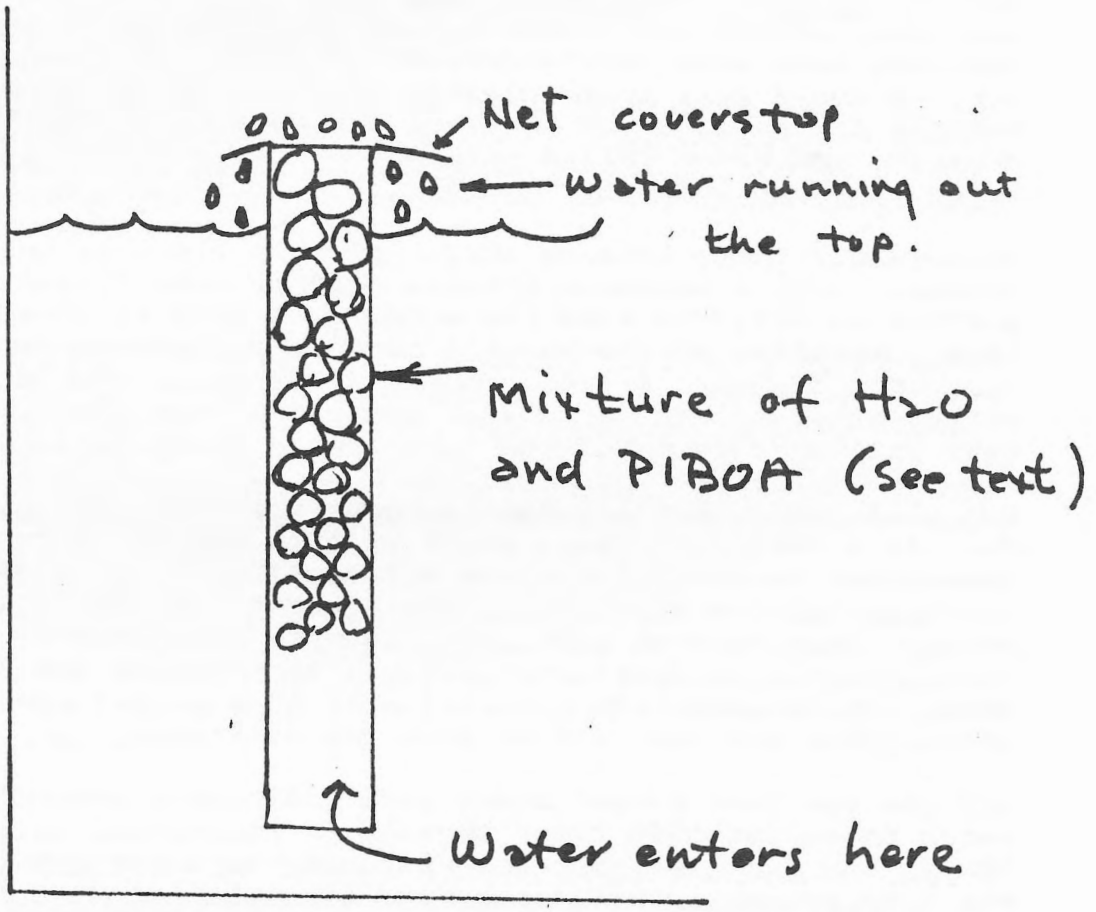

Fig. 1. Continuous water flow upward around captive PIBOA.

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Addressed Correction Requested

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