Nitrate Menace?

By Thomas A. Frakes

Everyday in aquarium shops across the U.S. hobbyists are tried and convicted of killing their pet fish. Cause of death? Nitrate poisoning.

Certainly water quality is an important factor in maintaining the health of marine aquarium fishes. However, for the past few years a number of authors in the popular aquarium hobby magazines have been recommending lower and lower safe levels for nitrate. With this barrage of articles it is no wonder that nitrate is increasingly being blamed for fish mortalities. Ultimately, the hobbyist who allowed these conditions is at fault.

The question that must be answered is what is a safe level of nitrate for fish and invertebrates.

Before going any further we must understand the terminology that is used to measure nitrate. The nitrate ion is a molecule composed of one nitrogen atom (N) and three oxygen atoms (O), hence, the scientific symbol NO₃. Nitrate is commonly measured for scientific work in milligrams of nitrogen per liter (mg/l) or, approximately parts per million (ppm). This is the Nitrate-Nitrogen (NO₃-N) level. Another scale that is used is the weight of the whole nitrate molecule in milligrams per liter (mg/l). This is the nitrate ion level (NO₃). Both scales measure exactly the same compound, much like miles and kilometers both can measure the same distance. The NO₃-N reading can be converted to a NO₃ reading simply by multiplying the NO₃-N level by 4.4.

To evaluate aquarium test kit results and any reports of safe levels, you must know which scale is being used and, if different, convert all data to the same scale. To call one a real or correct number and imply that the other is a wrong number, as some authors have done, demonstrates a lack of understanding of basic chemistry. For the remainder of this article, I will use NO₃-N levels expressed in milligrams per liter (mg/l).

The SeaTest® Nitrate test by Aquarium Systems uses the scientifically accepted NO₃-N scale as do several other manufacturers.

Claims Against Nitrate

What are the claims against nitrate? Mr. Albert Thiel recently recommended maximum nitrate levels of 1.1mg/l NO₃-N for invertebrates and 3.4mg/l NO₃-N for fish. The basis for these recommendations is experiments and conversations with others, yet no data or references are provided. Basically, he claims that "...rather low levels of nitrate in any form can seriously depress the water quality and result in aquariums that look 'drab' or in which organisms, fish, and invertebrates do not fare well." (Thiel 1992.) This nebulous indictment of nitrate as a toxic agent is purely circumstantial.

Similarly, John Tullock, in a series of generally informative articles, has suggested nitrate as a problem. In Anemones and Their Host Anemones (1992) he recommends nitrate levels below 2.2mg/l NO₃-N, suggesting that higher nitrate may cause "droopy" anemones.

In a later article on water chemistry, he notes that groupers may tolerate nitrate in excess of 23mg/l NO₃-N. However, "tangs and angels will generally refuse to eat if nitrate ion (NO₃) concentrations exceed 40 ppm." He thus suggests a more reasonable limit of 9mg/l NO₃-N for fish-only aquariums and below 2.2mg/l NO₃-N for tanks with invertebrates (1992b).

John O'Malley, another very experienced aquarist, and Question and Answer columnist for Aquarium Fish magazine, recently stated that "Elevated nitrate levels can stress most saltwater fishes." He goes on to state that some species simply will not survive chronic levels above 4.5ppm NO₃-N. (O'Malley 1992.) This conclusion seems to be based on personal observations and experiences and no data or scientific references are provided.

Can all these authors be wrong? Yes and no.

No, in that the basis for all of these recommendations is that good water quality is essential to maintaining healthy aquarium inhabitants.

Yes, in that the data supporting low level nitrate toxicity is purely circumstantial.

(continued on page 2)
Nitrate as an Indicator

It is understandable that aquarists may jump to the conclusion that nitrate is toxic. Only a few tools are available to most marine aquarists to diagnose a sick fish: gross physical signs, water color, pH, ammonia, temperature, nitrite, salinity, and nitrate. So when a fish becomes ill and the only parameter that is out of the "desirable" range is nitrate, it is easy to assume that nitrate is the source of the problem. This logic is flawed in that it ignores the role of microscopic pathogens, many of which cannot be observed with the naked eye and may actually reside internally. It also fails to consider other water quality parameters, such as dissolved organics, for which there are no simple tests. However, I do not mean to imply in any way that hobbyists should abandon nitrate testing, because it still is one of the best measures of overall water quality.

Public Aquariums

I will begin by pointing out that public aquarists for years have recognized that nitrate is a relatively non-toxic compound, frequently reporting levels in the hundreds of milligrams per liter. Spottet (1979) recommended an upper limit of 20mg/l NO$_3$-N, and more recently (1992) has raised that to 50mg/l NO$_3$-N for fish aquaria. Many public aquaria I checked with seemed to agree with this limit, although they all would prefer lower levels on general principle. Jim Anderson, of the John G. Shedd Aquarium, reported levels up to 70mg/l NO$_3$-N in their 300,000 gallon marine system (personal communication, 1992). A broad spectrum of "delicate" species have been maintained there in good health, such as four-spot, copperband, long snout, saddleback, and raccoon butterflyfish. Other long term residents include korean angels, yellow tangs, saflin tangs, and blue tangs. Jay Hemdal, of the Toledo Zoo, cited a range of 5 to 40mg/l NO$_3$-N for fish tanks (personal communication, 1992). This is very close to the 50mg/l NO$_3$-N or less maintained by Sea World of Ohio for fish (Pete Mohan, personal communication, 1991).

Some public aquaria, faced with governmental restrictions, are not permitted to discharge saltwater and cannot make any water exchanges. Pierce et al. (1993) reported an extreme condition caused by inability to make water exchanges. The nitrate level in EPCOT's Living Seas exhibit at one time approached 500mg/l NO$_3$-N, in spite of a very sophisticated water treatment system. Because of concern about this high reading a new denitrification system was installed that has dramatically lowered the nitrate level.

Of particular interest was the observation of Jane Davis, also of EPCOT, that certain tanks in the system developed head and lateral line erosion (HLE) when the nitrate level was above 160mg/l NO$_3$-N. The high level of nitrates was suspected to be the cause of HLE. However, when the fish were transferred to an outside holding tank on the same water system they recovered (personal communication, 1992).

Value of Testing

If nitrate is not particularly toxic, what is the point of measuring it? Of the public aquarists contacted, most agree that nitrate is a very useful indicator of overall water quality, and should be measured, along with pH, to determine when water exchanges are needed. If pH is low, less than 8.0, and nitrate is high, above 20mg/l NO$_3$-N, it is time to consider a water exchange. Other compounds that are impractical to measure may be at dangerously high or low levels. If the value of nitrate testing is primarily to determine the need for water exchanges, it may actually be counterproductive to reduce the nitrate level by means of a denitrification system. The resulting low level of nitrate would then not reflect the presence of these potentially harmful compounds.

Some aquarists try to maintain low nitrate levels in an attempt to control algae. It is much easier to do this by controlling phosphate levels (SeaScape® 1992). Water exchanges using a sea water exchange machine, such as Instant Ocean® sea salt or Reef Crystals® sea salt, would be a better approach to maintaining good water quality and helping control algae. In conclusion, the extremely low nitrate levels recommended by some authors and certain test kit manufacturers have not been supported by scientific research. It should be noted that Aquarium Systems, as the manufacturer of Instant Ocean® and Reef Crystals® sea salts, would gain financially by suggesting that hobbyists maintain the extremely low levels of nitrate advocated by some authors, because we make the salts needed for water changes. However, we stand by our longterm recommendations of 20mg/l NO$_3$-N for delicate fish, up to 40mg/l NO$_3$-N for hardy fish, and below 10mg/l NO$_3$-N for invertebrates. Any monetary savings to the hobbyist would be better spent on selecting higher quality, nontaken fish and a quarantine tank to reduce the risk of disease, the major cause of death in aquarium fish.

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[Ref. SeaScape®, 12(6), 1992, p. 236.]
treat. I learned this painful lesson one summer during a collecting dive in the Coral Sea.

While diving along a patch reef between two rocky cliffs, I discovered a small, 6-inch shrimp-like creature peering at me from under a large rocky slab. Its two stalked eyes followed my every move as I carefully lifted the slab. Once the protective rock was overturned, the shrimp was easily scooped up with my hand-net. In order to examine my quarry more carefully, I reached into the net and grasped the wriggling crustacean. The moment I seized it, a stabbing pain in my index finger forced me to release it. I had been pricked from a half inch laceration that went down to the bone. Suddenly I realized I was not dealing with an ordinary shrimp, but with a fierce predator that would become a subject of study for years to come.

Known as mantis shrimp, these crustaceans are formidable predators equipped with two razor-sharp claws which are used to capture prey. Like the terrestrial praying mantis, they can snatch prey by thrusting their barbed claws forward with lightning speed, no easy task underwater.

Although called mantis “shrimp”, these small, saccate crustaceans are only distantly related to true shrimp, and belong in an entirely different suborder. Over 400 species are distributed throughout tropical and subtropical seas, and they are common residents in sandy and rubble substrates, often building elaborate burrows under rocks or coral slabs.

Several species feed on commercial shrimp and are regularly caught in shrimp-trawl nets, occasionally in large numbers. Sorting through their trawl for shrimp, fishermen handle these creatures with respect or, preferably, not at all. They have appropriately given them the name “thorn-splitters” because the mantis shrimp’s sharp claws will inflict severe cuts if handled with bare hands.

Mantis shrimp resemble the small, terrestrial praying mantis in appearance, but some of the more formidable species grow to over 16 inches in length (no praying mantis ever reached this size). Even the tiny inch-long pigmy mantis shrimp, _Gonodactylus zacca_, is an aggressive predator, always searching for food. Armored with razor-sharp, jackknife claws, they can seize small fish with incredible speed and precision.

The strike of a mantis shrimp is thought to be one of the fastest movements in the animal kingdom, taking less than 1/1000 of a second.

Mantis shrimp have been divided into two groups based on the modification of their forelimbs: the “smashers,” which use their powerful claws for smashing open hard-shelled animals; and the “spearsers,” which use their barbed claws to impale their prey by spearing.

The claws of the smashing mantis shrimp are modified into heavy hammerlike protuberances used to strike the protective armor of hard-bodied animals. With repeated blows of awesome power a large individual can actually break open clams, snails, or crabs to feed on the soft tissues. A large 12-inch captive peacock mantis shrimp, _Hemisquilla enigmatica_, was reported to have cracked the safety glass of its aquarium. Biologists have reported the strike of the clublike claws of large smashers to have the power of a .22 caliber bullet!

The hunting strategy of a spearer is similar to the praying mantis, but involves the capture of small fish, shrimp, and other soft-bodied creatures. In striking position, the spearer stalks its prey. When the prey is within reach, the spearer thrusts its barbed claws forward with incredible speed, impaling the prey between the jackknife blades. An 8-inch spear-bearing mantis shrimp can devour a 5-inch fish in about four minutes.

Although the claws are primarily hunting weapons, they are also used in territorial combat. When two smashers fight, the defender will lie on its back with its tail coiled up as a shield to block the powerful blows of the aggressor. The tail is heavily armored with supporting ridges for structural strength to absorb these strikes. After a number of blows, the defender will usually retaliate. Uncoiling, the defender exchanges blows until the attacker assumes the coiled defensive posture. Often territorial battles last 15 minutes or more, and usually end with one of the combatants retreating. Once defeated, an individual has the surprising ability to later recognize the victor and avoid any future confrontation. This ability was once thought to be restricted only to vertebrates.

Territorial battles occasionally result in damaged or missing limbs, and, like all crustaceans, mantis shrimp must molt their outer shells to repair these appendages. After the molt their exoskeletons are soft, making them defenseless against predators and other mantis shrimp. Consequently, many are injured and killed during this period. Some species are even cannibalistic. A crustacean shell even hardens in one to two days.

In addition to their protective support structure, the tails are often brightly colored or ornately sculptured. The tails of the peacock mantis shrimp and the Pacific green mantis shrimp, _Odontodactylus scyllarus_, are decorated with bright yellow spots hidden under sliding flaps. It is believed that these spots startle a would-be predator. This is similar to the startling eyespot displays of some butterflies and moths.

The uncommon spinetail mantis shrimp, _Echinospindrella guerini_, has a tail that mimics a sharp-spined sea urchin. If attacked by a predator or threatened by another mantis shrimp, this species retreats headfirst into a crevice or burrow, blocking the entrance with its urchin-like tail, and discouraging the pursuer from further attacks.

Inch for inch, mantis shrimp are among the most powerful of all invertebrate predators. Although their predation strategies seem particularly ferocious, they are, after all, engaged in a quest for survival.

Anemone Propagation

By: Michael Paletta

In the Winter, 1992, issue of SeaScope, I described the techniques for propagating many types of corals. However, little has been published on the reproduction of anemones for marine aquariums. Small _Aiptasia sp._ anemones routinely bud off babies, but they are not desirable in reef tanks. Colin Lau, in the Spring, 1988, SeaScope, reported the sexual reproduction of the sand anemone (Heteractis muta), but reproduction studies on the lagoon anemone species have been lacking. Recently a rose-colored bubble-tipped anemone (Entacmaea quadricolor) reproduced in my tank. Because I have not seen this reported in any of the literature, I will describe the details in depth.

In January of 1991 I purchased a specimen approximately the diameter of a nickel (2 centimeters, or cm) when fully expanded. Under 1,000 watts of fluorescent aquarium lighting the anemone grew to approximately 5 inches (13cm) in diameter in a little more than eight months, with little direct feeding. Occasionally, a small piece of food offered to the fish would find its way to the anemone. I added a pair of yellow-banded maroon clowns (Premnas biaculeatus) which took up residence in the anemone. The female of this pair had the curious habit of taking large pieces of food and directly feeding the anemone. Over the course of the next six months the anemone more than doubled in size to approximately twelve inches (30cm) in diameter.

At this point I had to take the clowns out, as they had become too aggressive toward the rest of the tank’s inhabitants. Two weeks later the anemone moved from the top of the rocks to a dimly lit cave. The tentacles greatly reduced in size, and the oral cavity was expanded. I assumed that the anemone was dying. After two days the degenerating oral cavity looked as though it had been cut. The next morning the cut had developed on the other side of the oral disk, and by that evening had expanded across the entire diameter of the anemone. The next day two fully developed oral cavities had formed approximately where the original cavity was, and the incision that had started at the oral cavity extended halfway down the body of the anemone. By that evening the anemone had almost completely split in two.

The entire process of “mother” anemone splitting into two “daughter” anemones took approximately two days, with most of the splitting taking little more than a day. I did not take pictures, because, as I stated, I thought that the anemone was dying. Little did I know that my twelve inch rose bubble-tipped anemone was going to split into two eight inch anemones.

I hope this report sheds some light on the obscure reproductive methods of this species, and generates more interest in captive propagation.
Sea Notecard:

In response to the numerous comments and questions we receive, SeaScope will attempt to answer some of the more popular questions when space is available.

Sea Salts

Q: Recently, a salesman for a new brand of sea salt told me his salt was the only one that was nitrate and phosphate free. Is it true that all other brands have phosphate and nitrate?

A: No. Instant Ocean* and Reef Crystals* sea salts do not contain phosphate or nitrate. Because of inquiries such as yours, our packaging has been changed recently to emphasize this. The formulation of the two products remains the same, because neither product contained nitrate or phosphate before. Long ago we learned that the addition of nitrate and phosphate nutrients was not necessary or desirable, and they were deleted from the Instant Ocean* formula. Reef Crystals*, of course, never contained either compound, because it was designed specifically for reef aquariums.

Q: Why should I need two salt mixes if all fish and invertebrates live in the same ocean?

A: It may sound implausible that one sea salt formula is better for reef invertebrate aquariums while another is recommended for general aquarium use, but the fact is that an aquarium is not the ocean. While the composition of ocean water is very consistent, and the reefs are constantly being flushed by tides and currents, aquarium water is generally not changed regularly.

The chemical composition of aquarium water is constantly deteriorating partly because of the accumulation of by-products from chemical and biological processes. More importantly, some elements, such as calcium, strontium, iodine, and iron, are steadily being removed from the water through chemical precipitation and biological accumulation, as in the case of hard corals. These imbalances are not being corrected by new water brought by ocean currents. Regular aquarium water exchanges can help, but often are not done frequently enough. Supplements are an option, but the risk of overdosing is always present.

For over 25 years, Instant Ocean* synthetic sea salt has been the standard for scientific and hobby marine aquariums, including miniature reefs. It was formulated to duplicate natural seawater for scientific research. For scientific studies, a modified formula is not acceptable.

However, the use of a fortified salt formula, such as Reef Crystals* sea salt, can help to overcome the deficiencies of important compounds that occur in reef tanks. It also eliminates the problems associated with adding supplements and making major water exchanges. Thus, there is a need for two salt formulas: Instant Ocean* for scientific and general hobbyist use, and Reef Crystals* for invertebrate reef aquariums.

Calcium

Q: The amount of calcium in synthetic sea salt is biologically adequate. Some salt manufacturers say low calcium is desirable; some say high calcium is better. What should I believe?

A: Although some manufacturers insist that low calcium is preferable to elevated or enhanced calcium levels, reef aquarists universally agree that calcium levels higher than those found in natural seawater are optimal for coral survival and growth. To further illustrate this point, many European reef aquarists have found it necessary to add calcium supplements on a regular basis to their reef tanks. This is because the German brands of synthetic sea salt available to European reef aquarists have been formulated to have a calcium level 20% below natural seawater. A lower calcium level makes synthetic sea salt dissolve rapidly in very hard water without precipitation, but in soft or pure water this level is not adequate for corals. Water changes with a solution already low in calcium will not solve the problem. Calcium supplements or another brand of salt with a better balance of calcium are ways to provide an adequate calcium level to organisms that require it.

As reef organisms form shells or skeletal structures, they remove calcium from the water and use it to stimulate growth of these structures. Selecting a synthetic sea salt with enhanced calcium, such as Reef Crystals*, will provide captive reef organisms with the needed "food" to promote growth.
The Collection, Transportation, and Maintenance of Living Corals
By Edward J. Bronikowski, Jr.

For many years the Cleveland Aquarium exhibited a tropical marine display which the staff dubbed “The Invertebrate Tank.” Usually shown were varieties of sea anemones, urchins, sea stars, mollusks, and a few crustaceans. The collection consisted of specimens from different oceans, and their only qualification to be included in the exhibit was that they not eat their tank-mates.

Attempts to show representatives of the major classes of tropical marine invertebrates were only partially successful. Glaringly absent were specimens of living coral. Being an inland aquarium, the staff was forced to use those species available through local importers, which usually arrived in poor condition and were short-lived. The Aquarium’s efforts to import live corals directly met with little success. Usually the corals’ failure to thrive was attributed to rough handling during collection and deterioration of water quality during shipping.

In 1976 the curatorial staff was contacted by marine aquarium enthusiast Richard E. Perrin of Riverview, Michigan, (currently owner of Tropicarium, Romulus, Michigan) regarding our synthetic seawater formula. As it turned out, our newly befriended “hobbyist” had been pursuing to an extraordinary degree the cultivation of corals in artificial seawater. Favorable results with a few species encouraged Perrin to try others. However, his progress, like ours, was inhibited by a high mortality rate during shipping. In this case, though, a solution to the problem was found as the result of an accident and through subsequent observation.

A shipment for Perrin containing five boxes of five corals from South America arrived at the local municipal airport. Four of the shipping boxes were intact, but a fifth box had been punctured, apparently by a forklift truck and probably, according to the airlines, in South America. Almost all of the sea water in the fifth box had spilled. At the time of unpacking, the four intact boxes contained the usual “coral bouillabaisse”.

The yellow-faced angelfish (Euxiphipops xanthometopon) is one of the many species that has lived over 20 years at the Nancy Aquarium.

The Nancy Aquarium — Revisited
By Thomas A. Frakes

Last November I had the pleasure of visiting the aquarium in the Musée de Zoologie in Nancy, France, for a second time. This small aquarium, part of a zoological museum, takes a long-term museum approach towards the exhibits. Professor Bruno Condé gave us a personal tour of the exhibits and a behind the scenes look at the aquaculture and holding facilities.

It was gratifying to see some of the fish I observed on my first visit in 1986. For example, the Queensland grouper originally was a beautiful little fish only 6 centimeters, or cm, long. It now measures over a meter long. This species is known to grow to more than 9 feet and is feared by native divers on the Great Barrier Reef.

I have been eagerly awaiting an update to Dr. Condé’s marine fish longevity article reprinted in SeaScope, Summer 1986. It is not ready yet, but he gave me a list of his oldest fish on display as of February, 1993, that is quite impressive. Table 1 lists these fish, all over 20 years old, along with the acquisition dates.

How does he achieve these impressive results? In an era during which aquarists have been offered numerous types of “advanced” filter systems, each said to be the best, the Nancy Aquarium remains committed to simple foam blocks for basic biological and mechanical filtration.
...The Nancy Aquarium

...continued from page 1

Most of the display aquariums are equipped with surface skimmers that drain into filter boxes containing a large foam block. Water is drawn horizontally through the foam and returned to the tanks by means of either an airlift pump or a power head. The bottoms of the aquariums have a thin layer of decorative gravel and appropriate decorations. Some aquariums are equipped with a single UV sterilizer (15 to 30 watts for approximately 300 gallons).

One important feature of the maintenance program is the drop-by-drop water exchange system. Every tank has an overflow standpipe. Newly mixed Instant Ocean synthetic seawater is added constantly, by drops, to each aquarium. The excess drains away. The drip flow makes approximately a 40% exchange with new water each month.

Lighting varies from tank to tank, but most aquariums are lit by four 40 watt fluorescent tubes. Generally 2 to 4 of the tubes are Sylvania Gro-Lux bulbs, but some tanks have supplementary Actinic O3 bulbs. These conditions produce an abundance of Caulerpa algae in many of the exhibits that may be a beneficial supplemental food. The staff provides a varied diet of fresh and frozen natural foods, which contributes to the longevity of the fish.

Although the filtration system is relatively simple in design, it obviously meets the needs of the animals on exhibit. Two foam blocks approximately 2' by 5' by 20' tall seem to provide more than adequate filtration for each 300 gallon tank. The surface skimmer removes floating debris and surface-active films from the aquarium and traps them in the foam blocks, which function as a mechanical and biological filter. Most tanks have 2 filter boxes, so the foam blocks can be cleaned on an alternating schedule to avoid any serious disturbance of the system. The return water is aerated in the lift tube or when it splashes as it returns to the tank. Nutrient buildup and fluctuations are held to a minimum by the drip water exchange system. This relatively simple system has produced dramatic results. Of course, the use of foam blocks for aquarium filters is well known to freshwater hobbyists and breeders around the world.

In addition to the two long halls of exhibit tanks there are two Electric Eel displays in the lobby. One is particularly interesting. The aquarium is wired so that the regular pulses of electrical current produced by the eel control an electric clock. This clock hangs beside another normal electric clock. The two times are always nearly identical, an indication of the regularity of the frequency of the eel’s electrical pulses.

A specimen of Koran angelfish (Pomacanthus semicirculatus) has been in captivity at Nancy Aquarium since 1971.

An extensive aquaculture research project is located in the basement. It consists of mostly salmon and perch larval rearing, juvenile, and grow-out raceways. Filtration is provided by batteries of foam blocks, each with a hole through the center. The blocks are positioned on vertical perforated pipes that lead back to the recirculation pumps.

Finally, we saw an aquarium containing a breeding pair of grey Bamboo sharks (Chiloscyllium griseum). The parents have been at the aquarium over 7 years and are about 60 cm long. They live in a 300 gallon tank not on exhibit, in the rear of the building. The young and eggs from three spawns are being reared in holding tanks. They are grouped by size: egg to 10 cm, 20 cm, and 30 cm long.

In conclusion, Dr. Condé and his staff use simple but effective techniques and Instant Ocean synthetic seawater to create environments where exhibit fish can live long and healthy lives. The life expectancies of the animals in captivity are probably significantly greater than for similar animals in the wild.

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Table 1

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Date Acquired</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undulate triggerfish</td>
<td>Balistapus undulatus</td>
<td>6-68 (24 yrs.)</td>
</tr>
<tr>
<td>Purple surgeonfish</td>
<td>Acanthurus xanthopterus</td>
<td>8-12-71 (21 yrs.)</td>
</tr>
<tr>
<td>Queensland grouper</td>
<td>Epinephelus lanceolatus</td>
<td>3-17-72 (21 yrs.)</td>
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<tr>
<td>Turkfish</td>
<td>Choerodon fasciatus</td>
<td>12-19-72 (20 yrs.)</td>
</tr>
<tr>
<td>Saddleback butterflyfish</td>
<td>Chaetodon chippion</td>
<td>7-1-72 (20 yrs.)</td>
</tr>
<tr>
<td>Blue-girdled angelfish</td>
<td>Euphichopus navarchus</td>
<td>8-12-71 (21 yrs.)</td>
</tr>
<tr>
<td>Yellow-faced angelfish</td>
<td>Euphichopus xanthometopon</td>
<td>8-18-71 (21 yrs.)</td>
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<tr>
<td>Koran angelfish</td>
<td>Pomacanthus semicirculatus</td>
<td>9-9-71 (21 yrs.)</td>
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<tr>
<td>Six-handed angelfish</td>
<td>Euphichopus sexstriatus</td>
<td>12-18-71 (21 yrs.)</td>
</tr>
<tr>
<td>Threespot angelfish</td>
<td>Apolemichthys trimaculatus</td>
<td>4-1-72 (21 yrs.)</td>
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<tr>
<td>False skunk anemonefish</td>
<td>Amphiprion perideraen</td>
<td>9-28-71 (21 yrs.)</td>
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</tbody>
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...Living Corals

...continued from page 1

with just a few surviving specimens. The punctured box, however, had a fresh seashore odor and viable-looking corals.

Soon after being placed in an aquarium, the dormant coral polyps that were in the punctured box opened and appeared healthy. Only those corals or portions of coral that had been resting in a tank of residual water were dead. Encouraged by the flourishing corals, an exchange of information, ideas, and resources, in addition to cooperative collecting between public and private aquarists, led to the successful exhibition of living and growing Anthozoa.

Refining the methods of waterless shipping was a trial and error procedure. The pooling of water in the shipping container was the greatest threat to the live coral and most of our efforts were toward developing ways of keeping it out of all water. In preparation for shipment the coral specimens were removed from the water and allowed to drain on a grid away from the sun and wind. Within 45 minutes the specimens were ready to be packed. The shipping containers used were standard Florida styrofoam boxes fitted with an extra bottom grid of the same material. The grid arrangement kept the corals away from the water expelled during shipment.

We tried synthetic sponges to absorb expelled water, but wherever the coral was exposed to the damp sponge, necrosis would occur. The most recent collecting trip produced the on-site development of the most successful technique to date. Using locally available materials from a discount department store, a type of long absorbent bean bag was made by stuffing women's nylon stockings with Perlite. The stocking was stretched over a large mailing tube, filled, and the tube then removed. The Perlite is lightweight and absorbent, and the elongated pillows were found to be ideal for securing the coral in the shipping boxes. Vermiculite, with less irritating dust, might be substituted for the perlite in future shipments.

Upon arrival at the Aquarium, we gently removed the corals from the shipping containers and placed them in well aerated bath tanks with the same water quality as that of the display. Here the corals were allowed to rinse themselves of accumulated slime and mucus. After about ten minutes the corals were transferred to their permanent display. Close inspection of the bottom of the bath tank revealed many surviving hitchhikers such asurchins, shrimps, crabs, and mussels. These babies needn’t be thrown out with the bath water.

Newly acquired corals are a challenge to arrange in a naturalistic and attractive fashion, while maintaining an appropriate environment suitable to the specimens. Regular topdressing will mortally damage a coral colony.

Specimens of stony corals that need to be anchored have holes drilled into the non-living area of their bases. Using an electric hand drill with a 4 millimeter (mm) bit, a hole is bored to receive a length of plastic tube 4mm in diameter. The tube should fit very snugly after it is inserted. The rock that serves as base material, in this case a "honeycomb" rock from coastal Texas, is drilled in a similar manner. The orientation of the...
A Double Sex Inversion in *Genicanthus lamarck* (Pomacanthidae)

By Bruno Condé

The adults of all species of the genus *Genicanthus* show distinct sexual dichromism, or distinct color patterns, of the different sexes which are used for the description of species or varieties that correspond to a male or female phase. Relatively discreet in *G. lamarck* (Lacepède), the type species of the family, this dimorphism is very conspicuous in others, *G. bellus* Randall or *G. watanae* Yasuda and Tominaga, for example. A pair of each of these species was raised at the Aquarium in the Musée de Zoologie in Nancy, France, between 1981 and 1985, respectively.

As with many other Pomacanthids that have been the object of observations on sexuality, the *Genicanthus* are sequential protogynous hermaphrodites. The males, larger and fewer in number, swim in the company of several females. Several groups, or harem, can swim next to each other, the females circulating freely, seemingly, from one harem to the other. The largest male is dominant over the other males.

The two *G. lamarck* raised at Nancy since December 2, 1981, were acquired as juveniles and put in a 650 liter tank. A pair was formed in 1986 by the sex inversion of one specimen that had been a female. After this, courtship displays were frequent and similar to observations of this species in the wild (Condé and Terver 1987).

On March 19, 1992, a violent battle occurred between the two partners, at the end of which the female hid until April 13. When she reappeared her appearance was typical of a male. Fearing a severe rivalry between two specimens presenting the same color pattern, characteristic of a functional male, we introduced a small group of juveniles with female coloration, in the hope this would divide the attacks. This action was not necessary, because the antagonistic reactions were limited to several pursuits initiated by the original male.

After June 18, we saw a progressive return to female coloration. The yellow nuchal spot was scarcely visible. The longitudinal lateral-dorsal band extended again and curved posteriorly to rejoin the ventral edge of the tail, the two opposite edges of which were again bordered in black. The blue mark at the base of the pectoral was blunted. Only the pelvic fins remained dark black, a unique testimony of the preceding process of inversion. We noted, however, the beginning of decoloration at the tip of the pelvic fins, which became whitish, confirmed by Jun 30. This whitening was scarcely more advanced by the end of December.

The courtship displays were resumed, as before, on March 19, the black pelvic fin color not seeming to have any significance in sex recognition.

**Note the following:**

1. The duration of the female-male sexual inversion, as estimated by the modification of the color pattern, was less than 4 weeks (March 19 to April 13). The same process took 6 weeks, in an aquarium, for *G. semifasciatus* (Shen and Liu 1976).

2. The order of the appearance and regression of the characteristic male pattern was the same, taking into account the fact that the direction of the process was reversed. In particular, the pigmentation of the pelvis appeared rapidly, during the last days of the acquisition of the male pattern, and started from the base of the fin. The fin tips, however, stayed unpigmented for a quite long time. Conversely, the yellow nuchal mark, visible in large females (Moyer 1984), faded rapidly until it disappeared completely in our specimen.

3. The observation of a “female” with black fins could be the proof of a male-female inversion in the wild.

4. A regression of the male pattern to a female pattern has already been observed in some recently acquired specimens; this was the case, at Nancy, with a *G. melanospilos* (Bleeker) that regained the typical coloration of his sex once it had been acclimated.

5. It is significant that the presence of a functional male for 6 years in a restricted space did not inhibit the sex inversion of his mate. However, it seems that a process of inhibition explains the elevated sex ratio in favor of females (0.2:34, according to Moyer 1984) and the formation of harem.

**References**


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**Live Rock News**

As most of you know, Florida stopped the landing of live rock on February 12 of this year. Under the terms of the three year phase out it was to reopen the season on July 1 but only for a short time.

Now, in response to a lawsuit in Florida by live rock fishermen, a temporary injunction has been granted. This injunction will prevent the State of Florida from enforcing the ban on landing live rock from Federal waters. The ban on collection of live rock from state waters remains in effect. Since this injunction should remain in effect until the issues raised by the fishermen are resolved, it is not certain how long this will last. For now, at least, quality live rock is again available domestically.
coral is determined by the angle of the bore. A 4 or 5 centimeter (cm) stud of plastic tube is usually sufficient to secure the coral. Rotating the coral upon the axis of the tube will allow exact positioning. This technique can also be used to mount live sponges that have lost their holdfast.

The horny corals still attached to their original base rock can be mounted with the plastic stud. When little or no base rock remains, another mounting technique is used. Incorporated in this method is the unique cement-like product Thorite by Standard Dry Wall Products of Centerville, Indiana. The properties of Thorite make it an ideal solution for permanently affixing sea fans and sea whips. It is very adhesive to damp surfaces, sets within an hour, it is non-toxic even when partially set, and it is strong, even in salt water.

Horny corals such as sea fans are prepared for cementing immediately upon arrival or within a few days. The colony is removed from the water and the excess water is gently shaken off. Algae, sponges, and any other encrusting organisms are removed from the horny base up to the living edge of the colony. Excess moisture around the base is blotted with paper towels. The coral is then positioned on the rock base and cemented with a thick mix of Thorite. The cement is worked up to the living edge of the colony and feathered well into the rock base. With tooling, the Thorite takes on the texture of the rock base.

Plastic sheets laid over the coral will maintain humidity while the Thorite sets. By laying the coral and base horizontally, the setting Thorite is protected from water excreted by the coral. Coral that seems to be drying excessively is wetted every ten minutes or so with sea water carefully applied with a pipette.

The Thorite is usually sufficiently set within an hour, and after a quick rinse in a bucket of sea water the coral is placed in the display tank. Within a week or two the Thorite becomes seasoned and is at least partially coated with algae. If the feathering and tooling has been skillfully done, the bonding will be nearly invisible. Sea whips with little or no base are mounted similarly, but with some modification. Enough of the horny skeleton is exposed to provide an adequate surface for the Thorite to make a secure bond. The exposed horny stem is then inserted into a hole bored in rock and cemented with Thorite.

To be continued in Part II next quarter.
**The Orchid Dottyback**

*Pseudochromis fridmani*

By: Michael Paletta

History is replete with tales of individuals seeking something unobtainable. Jason and the Argonauts sought the Golden Fleece. Ponce de Leon sought the fountain of youth. And I sought to obtain the Orchid Dottyback (*Pseudochromis fridmani*). I realize that most hobbyists have one fish that they must have, but I doubt that many have contacted over fifty stores over the course of five years to try to obtain it. Why would someone go to this much trouble just to get a pygmy basslet (*Pseudochromis spabae*) that for all intents and purposes resembles the common magenta dottedback (*Pseudochromis porphyreus*)?

There are many reasons. First of all, the Orchid dottyback is exceedingly rare in the aquarium trade. It was only discovered in 1968, despite the fact that it lives in relatively shallow water on reef slopes from one to thirty meters deep. Secondly, if viewed closely it is easy to see that the coloration, while resembling that of the magenta dottyback, differs markedly. Unlike the monochromatic *P. porphyreus* that has the same pale purple throughout, the Orchid dottyback is deep violet with each scale trimmed in blue. This purple is so intense that it actually seems to hurt your eyes under certain lighting conditions, and this color does not fade as the fish gets larger. In addition, the Orchid dottyback has a dark purple bar that extends from the snout through the eye.

However, the most endearing quality about these fish is that, unlike other Pseudochromids, the Orchid dottyback does not share the pugnacious disposition that most others possess. On the reef, these basslets often travel in groups, and I have found that my three get along exceptionally well together. While they occasionally chase each other, there have been no torn fins or major fights to date. These basslets get along with all of their other tankmates as well, including a pair of Springer's dottyback (*P. springeri*). These are also from the Red Sea and are sometimes found on the reef with the Orchid dottyback. However, I probably would not trust the *fridmani* with like-bodied fish, such as firefish or small-bodied wrasses. I have seen them harass such fish in my tank.

Unlike most pygmy basslets, the Orchid is one species that is easy to sex. The main difference is in the shape of the tail. In the female the tail is perfectly round. In males the tail arches and meets at a sharp point. This gender difference appears to develop early. When I obtained my trio the fish were only 1" to 1 1/4" long and the difference in tail shape was readily apparent. The fish have now grown to 2 1/2" in length, on their way to an adult length of 4" and the tail shape has not changed. These basslets are cousins to the much larger groupers, which change sex as they get larger, and some may eventually change sex later on.

As with most Pseudochromids, the Orchid thrives in the reef tank, constantly picking copepods and worms from the rocks. They are not at all skittish and spend most of their time at the front of the tank. My fish eat virtually any kind of food offered them, including flake. Because by nature they are carnivores I try to feed them a preponderance of meaty foods including chopped shrimp, squid, urchin, and fish.

My description of this beautiful fish probably does not do it justice. However, if you are fortunate enough to encounter an Orchid dottyback in your dealer's tank, you will realize that you have the rare opportunity to acquire a fish that is not only stunning but also quite docile. Despite its high price tag, it is more than worth the cost.
Coral Farming in Detroit

By: Richard Perrin
Tropicorum, Romulus, Michigan

The segment of the marine aquarium hobby usually referred to as "miniature reef" aquariums has a strong fascination for many of us. I have been interested in marine aquariums since a trip to Florida in 1957. By 1970 I was culturing invertebrates such as Ricordia and fire coral. As owner of Tropicorum, I have been involved in the wholesale and retail trade since 1980. Over this time I have observed the areas from which these "flower animals", especially the stony corals, can be obtained dwindle to primarily Indonesia. The thought that Indonesia might also bow to environmental pressure and stop supplying these animals has caused me to become deeply involved in the captive breeding of as many of these organisms as possible.

I own a large greenhouse in the Detroit area, originally designed for orchid culture, and this made it possible for me to experiment in the propagation of corals. I was able to take advantage of the volume and variety of organisms passing through my import business to pick the best and most colorful specimens for cultivation. I devoted 25% of my 3,600 gallon capacity to various cuttings of Cladiella, Sarcophyton, Xenia, and Neptia, as well as individual Actinodiscus on rocks. I use vat type tanks and, contrary to contemporary wisdom, I have had 2 to 6 inches of dolomitic limestone on the bottom of each. These methods have not changed a lot since the late 1960's. Aeration and circulation are provided by air/water lift tubes constructed of 1/2 inch PVC pipe with an elbow at the top. These draw water from just above the rock and are positioned on diagonal corners. They are directed along the length of the tank to provide a general circulation around the tank. An underwater plate is under a small portion of the bottom, less than 10%, to provide biological filtration.

I expected that the anaerobic bacteria likely to proliferate in this substrate would help keep nitrate and phosphate levels down. The strong aeration prevents the inevitable hydrogen sulfide from causing any problems. The salinity is maintained at 1.022 using Instant Ocean sea salt, and calcium is maintained at about 450 milligrams per liter (mg/l) by addition of calcium hydroxide. More recently I have added strontium following the recommendations of Alf Nilsen. The vats are stocked with live rock at one pound per gallon. This system, combined with macroalgae growth, such as Caulerpa sp., and infrequent water exchanges, has maintained nitrate below 3.5 mg NO3/1 (0.8 NO3-N mg/l). Hair algae problems have been non-existent.

Encouraged by my success at propagation in these systems and because I wanted to work on more species, I decided to expand. I was disappointed with the 25% light transmission of the original greenhouse, so the new one was planned with improved glazing and a better angle to the sun. This facility came on line in November 1992.

The new greenhouse has eight 6' x 16' x 2' deep plywood vats lined with plastic for a total capacity of about 12,000 gallons. Currently, a 1 horsepower Gast blower powers eight 1/2" lift tubes in each vat. About 5-10% of the bottom has an undergravel plate that functions as an undergravel filter. The rest is static gravel.

The concept of controlling nutrients by means of macroalgae seems to work. During the summer up to a bushel of algae, primarily Caulerpa, is harvested each week. This seems to be a cost effective means of water quality control, and the algae can be sold along with the corals.

Yellow water has at times been a problem. I occasionally use activated carbon. Recently we have installed 3 large protein skimmers based on suggestions from Mike Paletta and Julian Sprung. These are particularly useful for curbing fresh live rock, which liberates tremendous amounts of organic material the first few days after we receive it.

Another suggestion from Mike was to periodically add potassium iodide as a supplement. This has sharply increased the reproduction of pulsing Xenia.

Current plans include another greenhouse with an additional 18,000 gallons in vats scheduled for late 1993. The tanks will hold 1 1/2 tons of tufa rock each, with coral cuttings positioned in trays on top.

This is just a start. In the not too distant future animals for reef aquariums may be tank reared, and wild caught fish will be a thing of the past.

What's that brown spiky thing?
The Marine Aquarium as an Educational Tool
By: Robert Day
Ph.D. Candidate and Graduate Teaching Associate at the Ohio State University, Department of Zoology, Columbus, Ohio

One of the most important undergraduate classes for fledgling zoologists at Ohio State is "Introduction to Zoology", or "tip-toeing through the taxon", as it's known to the faculty. It's a tough boot-camp of a class that really sorts the tugs from the sea cucumbers. In nine frantic weeks we lead (or drag) students through 13 phyyla and hundreds of representative species.

In recent years the teaching staff has tried to incorporate more live specimens into the class, because we have found that students become excited and enthusiastic about visual aids that slither, creep, or wiggle across their desk. In contrast, they seem to lose interest quickly in anything stuffed, pickled, or nailed to the base of a sealed glass box. Because of the global environmental situation, we also feel a duty to promote respect for living things and the value of biological diversity, without compromising student contact with real animals or increasing class costs.

This seems like a formidable list of demands, but many of them have been met using a carefully managed three tank, 220 gallon marine aquarium system (Instant Ocean Sea salts) that I thought might interest SeaScope readers, especially those involved in science education.

The system consists of a central sump, 3 feet tall by 4 inches, that supplies the 3 aquaria. It is equipped with a small trickle filter and a protein skimmer supplemented with ozone. The 110 gallon aquarium has two small undergravel plates, 12" wide, at each end of the tank, powered by pumps. The whole bottom is covered by 3" of crushed coral. Two 55 gallon tanks are stacked. The water flows from one to the other and then back to the sump. Lighting ranges from very bright (six 110 watt VHO and two Actinic bulbs over the 110 gallon tank) to dim (three 20 watt daylight bulbs over the lower 55 gallon tank).

Our system is unlike most hobbyists tanks because its purpose is quite different. We avoid large expensive specimens and ignore mainstream ideas of what is or is not "desirable". Instead we use cheap (better yet, free) hardy species that can stand frequent removal and examination by up to 80 students a day. We favor anything that will breed explosively and colonize rapidly. Tiny species are welcome; they help improve student microscopy skills. Drah, cryptic species are also fine; the teach students to be observant and identify species by looking for key taxonomic features. Bristle and spaghetti worms, Aiptasia, isopods, amphipods, and all the other so-called "undesirable" organisms are ideal. They demonstrate the biology of their taxa perfectly well and our system contains nothing expensive for them to exclude anyway. Widespread predation? That's fine too; we use it to show ecological relationships between organisms. Lush algal growth? Great! It increases the number of microhabitats and thus contributes to invertebrate and...
Part II
The Collection, Transportation, and Maintenance of Living Corals

By Edward J. Broniwowski, Jr.

Continued from the Spring '93 SeaScope®

In addition to basic aquarists, certain environmental demands must be met for successful long-term coral culture. These demands include adequate light, water circulation, water quality, and food. Perhaps the single most important factor is abundant light. Corals require brilliant light to photosynthesize zooxanthellae algae cells growing symbiotically within their body tissues. If the zooxanthellae, the coral colony will probably fail. The inadequate lighting system at the Cleveland Aquarium was replaced by two extremely efficient metal halide lamps of 1,000 watts each manufactured by General Electric Company of Cleveland, Ohio. The lamps are suspended with their lenses 60 centimeters (cm) above the water's surface. The lamps efficiently convert electricity to light so relatively little heat is produced. Now the daily temperature fluctuation is kept to within 1°C. Also, in the quality of light is high, about 4,800 lux approaching sunlight in color. Following the installation of the metal halide lamps, some of the corals withdrew for several days until they adjusted to the brighter light. The rewards of the increased illumination are apparent; the individual coral polyps are expanded more than before and have been enhanced with a deeper color from the zooxanthellae - and some specimens that were previously just surviving are now overgrowing other corals.

The aquarium used for the coral display is of plywood construction, 200 cm long, 85 cm wide, and 96 cm deep, with a total volume of about 1,100 liters. The tank is in two sections. The exhibit section is 157 cm long by 85 cm wide with a reservoir section 43 cm by 85 cm. The exhibit section has two subgravel filter plates covering the entire bottom. Each filter plate is outfitted with a single 3 cm diameter airlift pipe topped with a 90° elbow directed diagonally across the surface. The reservoir section has one subgravel filter plate with a single 2.5 cm diameter airlift pipe directing water to the exhibit section. Water is returned to the reservoir via an overflow from the exhibit. The subgravel filter plates of both sections are covered with a 7 cm layer of crushed dolomite graded from 3 to 6 millimeters (mm). A thin decorative layer of cockleshells covers the dolomite in the exhibit section.

Water circulation is very important in the coral exhibit. Those corals in the most turbulent areas appear to do better than those of the same species in areas of less current. The main force for circulation is provided by the system's twin 5 cm airlift pipes that power the subgravel filter plates. Additional current is supplied by two air diffusers. On the whole, the currents produced in the exhibit appear random in direction but are actually regular to the individual colonial corals mounted in a permanent position. Some of the older sea whips have grown into peculiar shapes and we suspect that the localized regular currents are the cause. Sea whips of the same species located in positions of truly random currents have grown into more natural shapes.

The average water conditions are a specific gravity of 1.025, or a salinity of 34 parts per thousand, and a temperature of 26°C. Water quality is fairly steady with a pH of 8.3, and the nitrates rarely rise above 20.0 milligrams (mg) NO₂⁻/N/Liter.

Water quality is maintained by frequent water changes. Ideally, once each month 90% of the water is changed at one time. The system is simply drained and refilled with new water of the same specific gravity and similar temperature. To avoid drying the corals during the water changing procedure the metal halide lamps are switched off. As the tank is being refilled, the corals are occasionally moistened with the incoming water. Within an hour of the water change the corals are back in full bloom.

The exhibit is fed two or three times each week. Two of the feedings are very heavy and the other light. The usual fare of a heavy feeding includes individual feedings for the large-polyped corals with frozen adult brine shrimp or frozen krill that we administer with a cooking baster. The small-polyped corals are allowed to feed on a mixture of frozen foods and vitamins emulsified in an electric blender. The mixture may include brine shrimp, krill, squid, green shrimp, or smelt. About 150 grams are prepared and poured into the tank. The airlift pipes of the subgravel filters are shut off so the air diffusers circulate the emulsion around the corals. Saturation feeding in this manner is finished in 45 minutes, after which the airlifts are switched on again. The filters clear the water within half an hour.

The stony corals that continue to thrive in the exhibit include brain corals Diploria strigosa, D. labrinthiformis, Colofophyllia natans, Meandrina meandrina, Mycedypthiria sp.; rose coral Mancina areolata; flower coral Eusmilia fastigiata; large flower coral Muraena anulosa; star coral Diadecos stoklesi; large star coral Montastrea cavernosa; staret coral Siderastrea radians; and porous coral Porites astroides. Several species of horny corals have prospered as well, such as the sea whips Eunicea sp., Muricea muricata, and Plexaura sp.; the slimy sea plume Pseudoptergorgia americana; and the common sea fan Gorgonia ventilana. Also flourishing are the false corals Ricordia floridana, the stinging coral Millepora alcicornis, and the knobby zoanthid Polythoa manubrostris.

Some of the coral colonies have grown exceptionally well. One sea whip arrived as a small bud at the base of a sea fan. Several months later it had grown to over 30 cm, and its continued growth was limited by the depth of the aquarium. A specimen of stinging coral weighing approximately 100 grams when collected grew to 240 grams within three years. While this colony has since died, other colonies of stinging coral continue to grow. It is suggested that perhaps the stinging coral colony reached its maximum size and then gradually failed. In another instance, a sea fan is being engulled by the growth of a knobby zoanthid.

We have cloned some of the sea whips, although it is too early to tell how large they will grow or in what shape. Cuttings about 3 cm long were taken from some of the most vigorous sea whips and these were girdled very near the cut. The horny stem was then implanted in Thorite and cemented to a rock. Within a few months the clones have tripled their size and some are beginning to branch out.

Establishing something of a balance among the inhabitants of the coral exhibit requires patience and careful observation. In our system, populations of gammarus shrimp and red bristle worms eat many of the foods missed by the corals, and additionally aid in the prevention of detritus within the filter bed. Algae growth that could interfere with the control of the coral system is controlled by long-spined urchin Diadema antillarum, edible urchin egg Tripneustes venustus, slate-pencil urchin Eucidaris tribuloides, and deer cowrie Cypraea cervus. The overall exhibit is enhanced by brittle stars Ophiocoma sp., banded coral shrimps Stenopus hispidus, feather duster tube worms Sabellastarte magnifica, various encrusting sponges, and a variety of other invertebrates.

Some animals, whether introduced by accident or design, may interfere with the well-being of more desirable species, and so must be controlled. The arrow crab Stenorhynchus seticornis, some hermit crabs of the family Paguridae, certain carnivorous sea stars of the class Asteroidea, and most anemones of the family Actiniidae can be injurious to coral specimens. Probably the most troublesome is the infamous pale anemone Aiptasia pallida. Through reproduction by budding its numbers can increase dramatically and it can completely overwhelm a colony. This anemone can be controlled somewhat by physically removing individuals during water changes. The pink-tipped anemone Condylosticta gigantea will also damage living coral, but it is very easy to control and may even be displayed with the coral if not allowed within stinging range of the colony.

While we have had a good measure of success with live corals with the system described, it is far from the better system we hope to design as resources become available. The present system evolved from materials on hand and was produced for a few hundred dollars. A new and improved system needn't be much more costly. Improvements might include a pair of dump buckets similar to those designed by Paul Seiswerda of the New England Aquarium. They would simulate a rhythmic surge to encourage natural shaping of growing corals. The metal halide lamps could be color-corrected with acetate filters. Large remote biological filter beds would be more convenient and would allow for more precise control of feeding. Finally, a deeper aquarium would give more room for growth to the water's surface.

Editor's Note:
Edward J. Broniwowski, Jr. is presently Director of Husbandry at Florida Aquarium in Tampa, Florida. When this article was written he was Co-Chief Aquarist at the Cleveland Aquarium in Cleveland, Ohio.

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...Educational Tool
...continued from page 2

pros (single cell) diversity, as well as reducing nitrate levels.

The city water in our area seems to be cursed by the angel of death, so we use only distilled. Because the supply is limited, even small water changes are a rare luxury. We generate generous doses of commercial (SeaGarden algae nutrients) and home-made iodine-rich trace elements daily, and believe it or not, we also add nitrates and phosphates to the system. (I can hear you all cringing!) This prevents reproductive disintegration of our macroalgae and maintains modest microalgae growth, although when we test for nitrates we find hardly any. (Now who's crazy?) The way some aquarists rant and rave about the "evils" of microalgae, an outsider might believe it to be some form of radioactive toxin. In fact, it's a perfectly natural part of any coastal environment. If you peer into the shallow water of the Florida Keys shoreline, you'll often see dense stands of it teeming with marine animals. One potential problem with lush algal growth in a closed marine aquarium is the yellowing of water by algal pigments, but we've found that this can be easily prevented by using ozone. To prevent algae from over-growing the entire system, we occasionally harvest a few handfuls, part of which is used for research elsewhere. The rest we purée into an "algal slurpee" and return it to the tank.

In many ways our system resembles the highly diverse ecology of the Florida Keys shoreline and quiet residential canals rather than a reef. The same water circulates around all three tanks, but by varying conditions in each (light levels, turbulence, and predator distribution) we've been able to generate ecological partitioning such that each tank holds slightly different species and the total biological diversity is higher than in a single tank of equal volume.

Every one of the 13 main phyla we cover in class is represented in our tanks, which we estimate house a little in excess of 100 animal species, perhaps 3 times that if we include the microscopic algae and protists. Most of these came in as "piggyback" colonists on Floridian algae collected as part of my graduate research (The Cell Biology of the Caulerpales) and, therefore, didn't cost us anything. Others were donated by local aquarists or by the Columbus Zoo Aquarium with whom we enjoy a wonderful symbiosis.

The system is environmentally friendly since anything we show our students goes back into its tank alive and is used again and again. We purchase very few, if any, new specimens each year and most of our fish are tank-raised species, although we do accept specimens from local aquarists if they leave town. This system saves money and shows the students that a responsible scientist can study life without depleting natural stocks.

Some of our students have lived in Ohio all their lives and have never seen the ocean. The range of different facial expressions on their first encounter with, say, a pencil-urchin has to be seen to be believed:

student: "Does it bite?"
prof: "No, hold it in your fingers."
student: "Aren't they poisonous?"
prof: "No, it's just a pretty ball that you glued some sticks onto."

prof: "No, it's real, see? It's moving. Go on, hold it."
student: "It's real? OOOOOOOOH!"

This type of marine aquarium is certainly not for everyone. Some more traditional aquarists may even think it ugly (all that algae, swarms of small crustaceans, and literally thousands of small polychaetes). However, beauty is in the eye of the beholder. Our system is easy to maintain, extraordinarily cheap to run, and spectacularly diverse. If you're a hobbyist fascinated by small animal diversity and have access to an initial source of marine algae, this can be a cheap and easy alternative to the "reef" tank. If you are a science educator, I heartily recommend this cost effective, interactive tool that gets the students to class early, keeps them late, and introduces them to biological principles in a way that text books and preserved specimens alone can't match.
Red Sea Reef "Mesocosms" in Monaco  
By: Thomas Frahes

In 1988 when the popularity of miniature reeds and wet/dry trickle filters was still on the rise, I had the opportunity to attend the Second International Aquariology Congress in Monaco. One paper in particular intrigued me, a report by Professor Jean Jaubert on a system that created a living reef of hermatypic corals (corals requiring strong light). Dr. Jaubert's office and laboratory were nearby at the University of Nice, and I was able to arrange for a visit to see his aquarium. I was impressed by the simple system he had devised to maintain successfully a broad spectrum of reef organisms including many corals, Tridacnid clams, urchins, crustaceans, worms, and fish. The system consists of an under gravel plate covered with about 2 inches of living coral sand 2.3 millimeters (mm) in size, a large air stone in the back corner for aeration and circulation, live rock and corals, and natural daylight supplemented with metal halide lights. I presented photos of the tank at MACNA1 in Toronto in 1989 to show hobbyists that alternative methods of reef keeping exist.

Over the last five years, Dr. Jaubert has been actively involved in developing his methods further. He and the staff of the aquarium at the Musée Océanographique in Monaco have created a number of model Red Sea reef exhibits. The results of their work were presented at the Third International Aquariology Congress in Boston in April, 1993. Part of the presentation was in the form of a video prepared by Ms. Nadia Ounais, director of the aquarium. This video was quite impressive and is the basis for this report, along with supplemental data and other published papers.

The Monaco Aquarium, host to over one million visitors annually, houses 90 aquariums and over 4,000 specimens. Since 1989 the aquarium staff has been creating what Dr. Jaubert refers to as "mesocosms", enclosed experimental ecosystems. Ranging in size from 260 gallons or 1 cubic meter (m^3) to 10,500 gallons or 40 m^3, the water quality is maintained by the methods described in Dr. Jaubert's patent (1991). In these quasi-natural ecosystems, all the groups of animals are kept together: fish, corals, crustaceans, mollusks, annelids, plants, and others.

Natural Water Purification

The water is purified by natural processes. The system utilizes a false bottom grid with a layer of coral sand over it. Unlike an under gravel filter, there is no forced circulation through this layer, creating a body of water that is deficient of oxygen, or anoxic, under the plate. The water in the aquarium above the plate is well oxygenated. ...continued on page 2
Live rock, corals, and most of the animals reside above the plate. The gravel bed is usually about 2 inches thick. Ideally, if the bed is the proper thickness, the water under the plate will be anoxic with about 1 part per million (ppm) oxygen, but not anaerobic with zero oxygen. This reduces the risk of hydrogen sulfide production. A gradient of water with high to low oxygen content exists in the bed, controlled by diffusion. Organic and nitrogenous wastes are gradually broken down biologically in this bed of living sand. Nitrate levels are generally well below 0.5 milligrams per liter (mg/l), with test tanks noted to be around 0.01 mg/l nitrate (Jaubert 1989).

High levels of light are available for the corals, provided by metal halide lights (Osram HQI, 5200K) and, in some cases, a skylight. For example, the 40 m³ tank has ten 1000W metal halide bulbs operating 14 hours a day.

The new larger aquaria (15 m³ and 40 m³) with moderate fish loads use sand filters and some supplemental pumps for circulation, but the living sand on the bottom is the primary purifier of the water. Air stones in these tanks are operated only at night. Water exchange volumes range from nearly none to a maximum of 10% each month. Although a broad range of fish species are kept in the 40 m³ tank, feeding is restricted to 100 grams dry weight once a week. No supplements are added and no chemical filtration is used (Oumais, personal communication 1993). These aquaria therefore appear to be truly natural systems, using the bacteria, worms, and other microorganisms in the sand and live rock to process any wastes that are not consumed by the actively growing corals.

**Coral Growth**

Yes, the corals do grow rapidly. Ms. Oumais's video shows the development of numerous coral heads over a six month period, demonstrating growing success as various hard corals battle each other for space. The 40 m³ tank is home to forty genera of hard corals and eight genera of soft corals, including the delicate pulsating Xenia from the Red Sea. To control the competition for space, the corals are pruned regularly. Branches or pieces are carefully broken off and cemented to a piece of rock, after which they are transferred to the 15 m³ nursery trough. After a month or so they recover from the trauma of being moved and begin growing again. Then they are used to decorate a new aquarium. One exhibit was stocked with cuttings spaced at 1 foot or 30 centimeters (cm) intervals. After 2 years the support structure was nearly covered with live coral. Ms. Oumais reports that the animals act naturally in this type of environment, with many fish species spawning and even some corals, such as Stylophora sp, reproducing sexually.

**Mesocosms vs. Natural Reefs**

Scientific studies have been performed to compare the mesocosms with natural reefs. Measurements of calcification and productivity in the exhibits closely match data from a 6 m³ respirometric chamber positioned in the Red Sea over a patch of coral (Jaubert, Oumais, and Thevenin 1993). The authors found similar calcium and carbon budgets in both the exhibits and the chamber, and observed calcium carbonate precipitation and dissolution in both studies. These calcium and carbon budgets should be of particular interest to reef hobbyists. Some reef aquarium hobbyists have tried to maintain high pH with buffers or Kalkeister additions. Others have tried to balance daily pH fluctuations by using the lights on turf scrubber systems to keep the pH up at night. The mesocosm approach, however, allows natural daily fluctuations to occur. Jaubert (1991) reported daily pH minimums around 7.8 measured at 8:00 a.m., and daily maximums around 8.25 measured at 5:00 p.m.

Several media are suggested for the bottom sand. These include sand from marl, crushed coral, or natural sand made up mainly of foraminifera shells, sized at 2-3mm (0.18 inch). With these materials, the mesocosms maintain high calcium levels reported at 460 to 520 parts per million (ppm) calcium ion. It is apparent that as calcium is used by the corals to build skeletal material, the daily dissolution processes replace it in the water. A combination of low pH in the mornings and organic acids in the gravel may account for the relatively high calcium levels observed. The levels of other essential skeletal elements such as strontium may also be maintained by using natural products such as crushed coral.

I would like to remind readers that these are not just coral aquaria. Many species of fish and invertebrates are kept together in these systems. As more information becomes available about this exciting method of aquarium keeping, I will try to pass it on.

---

**Diagram**

Schematic Cross-Section of the Aquarium

**Mesocosms vs. Natural Reefs**

- Tubipora
- Millepora
- Favia
- Pocillopora
- Favites
- Storeaporpora
- Goniatrea
- Stylophora
- Platygrya
- Acropora
- Leptoria
- Porites
- Montastrea
- Goniopora
- Leptastrea
- Pavona
- Cyphastrea
- Helfofungia
- Trachyphyllia
- Fungiia
- Euphyllia
- Heteropora
- Cataracta
- Halimeda
- Plagioderma
- Galaxea
- Turbinaria
- Scolyma
- Lithophyta
- Lobophyllia
- Sarcophyta
- Symphylia
- Sinularia
- Anthelia
- Dendronephthia
- Cladiella
- Xenia

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**Bibliography**


The same aquarium with a 150W heater would level off just over 90°. To maintain a desired temperature of 78° this heater would operate only one third of the time. These values will vary

in individual aquariums depending on the amount of lighting, number of pumps in use, and amount of aeration, as well as other factors unique to the system. Table 2, taken from the Visi-Therm® heater instructions, can be used to select an appropriately sized heater. It is based on aquarium size and the desired temperature difference between the normal room temperature and the desired water temperature.

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**HEATER SIZE IN WATTS**

**Safety Considerations**

There are a number of safety considerations that hobbyists should be aware of when operating a heater. First, the heater should be plugged into an outlet protected with a Ground Fault Circuit Interrupter (GFCI). This could prevent a serious shock if the heater breaks. GFCI outlet boxes that plug into existing outlets are now readily available. It is a misconception that the circuit will be automatically turned off if an electrical device such as a heater breaks. In fact, since most glass and acrylic aquariums are well insulated, the circuit will not be interrupted until the aquarium is electrically grounded. This grounding usually occurs when a hobbyist reaches into the aquarium.

Hobbyists should therefore avoid situations that could cause the glass heater tube to break. Thermal shock is the most common cause of broken heaters. It usually occurs during a water exchange. The water level is lowered past the point where the heating element part of the heater is exposed. The heater is still plugged in and the glass becomes very hot, too hot even for temperature-resistant borosilicate glass. The tube cracks when cool water is poured into the aquarium.

Physical impacts are another cause of breakage. These can be caused by large agressive fish or even by hobbyists performing tank maintenance. It is important to position the heater securely in the aquarium or to devise some sort of protective guard around it. A protective tube

must be carefully designed so that it does not restrict water circulation around the heater.

**Check Heaters Daily**

It is a good practice to check both the heater and the water temperature daily. This can be done while feeding the fish and inspecting the pumps and filters. Proper heater selection and close observation can greatly reduce risks associated with heaters while providing a stable temperature environment for your pets.

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**From the Philippines**

By: David Bashin
Peligica East, Inc.
Mabatai, Philippines

I am a U.S. citizen living and working in the Philippines, and I am also an avid salt water hobbyist. I feel there are a number of issues concerning the aquarium hobby and its relationship to the coral reef that need to be addressed from this part of the world.

**Net Collection Training**

The first issue concerns a recent article in the February, 1993 Marine Fish Monthly by Mr. Steve Robinson regarding cyanide use in Philippine and Indonesian ornamental marine fisheries.

**TABLE I**

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**TABLE II**

**Net caught Philippine fish in a custom artificial coral reef exhibit created by David Bashin.**

I feel that this topic needs some clarification. I am not about to refute some of Mr. Robinson's claims. The coral reef, which to me is one of the most fabulous places on earth, is indeed the victim of a frequently destructive fishery.

What I am not in agreement with are Mr. Robinson's ideas for a solution. It is impractical to think that retailers and hobbyists on the other side of the world can exert enough pressure to bring about a cure. The problem starts here, and chances for a successful resolution are far better if a solution is sought here at the source.

There are a number of people here who export only net-collected fish. They are having a difficult time financially; particularly now that many stateside sellers of fish are claiming that their fish are net caught and drug free, whether they are or not. However, if these net collectors were to become successful, older and more established exporters might consider changing their collecting practices, particularly if the means to do so were close at hand and within their budget.

While Mr. Robinson, International Marine Life Alliance (IMA), and the Haribon Foundation are to be applauded for their ground breaking efforts in training divers in net collection techniques, their success has been limited. It takes four to five weeks to thoroughly train fishermen and unfortunately, due to limited funding, the previous IMA/Haribon "Netsman" project could only afford to spend about one week training. Using a large and properly equipped boat could cut training time and permit more efficient use of the available funds and personnel.

A 64 foot ocean-going trimaran is nearing completion at our site in Trece Martires, Cavite. When finished this vessel could serve as a base for a Philippine foundation whose primary purpose is to train and educate fishermen in net collecting skills, proper handling and holding procedures, and the importance of coral reef protection and preservation. The services of this
Sulu Pilot Project

Recently, Ferdinand Caz and I visited the Sulu Archipelago in the Philippines. The giant rabbitfish, S. verrucosa, a rare and endangered species, is found in the Sulu Archipelago and it is considered an important marker species for the health of the ecosystem. We also observed the coral reefs, which are a vital part of the marine biodiversity in the region.

Fancy Plants

Fancy Plants is a popular aquarium decoration in the Philippines, known for its vibrant colors and unique shapes. They are commonly used to create an underwater landscape in aquariums. Fancy Plants are available in a wide range of colors and shapes, and they are marketed as being easy to maintain and perfect for beginners.

Export Ban

The Philippines has implemented an export ban on certain marine species, including live reef fish, coral, and other marine ornamentals. This ban was put in place to protect the country's marine biodiversity and to prevent the loss of these species due to over-exploitation. The ban affects both domestic and international trade, and it is expected to have a positive impact on the conservation of marine resources in the Philippines.

Exports have the potential to contribute to the economy, but they can also lead to over-fishing and other forms of exploitation. The export ban is a step towards sustainable management of marine resources, and it is supported by both the government and the international community. The ban is expected to be a model for other countries to follow, as it demonstrates the importance of conservation and sustainable development.