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Starfish: Considerations for the Common and (Commonly Misunderstood) Varieties
by Anthony Calfo

ReefSlides - Those Gorgeous *Gorgonians*!
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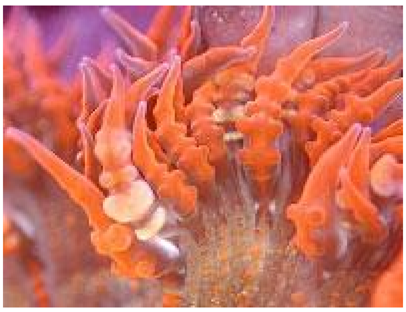
Tank of the Month
This month we are featuring Andy Bajc's (Andy) awesome reef tank.



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Cover: A beautiful, but unidentified gorgonian. Photo by Aleksandr Pyndyk.

Starfish: Considerations for the Common (and Commonly Misunderstood) Varieties

by Anthony Calfo

With progress in natural marine aquarium keeping, increasing numbers of so-called "starfish" successfully reproduce. Applications like deep sand beds and refugium habitats seem to support such success. Some species may become a nuisance by their sheer numbers and prolific nature like *Asterina*, while others are clearly harmless or helpful by stirring detritus or consuming algae, for example.

This article covers a range of sea stars kept in aquaria, including the deliberate and incidental imports, the decorative and nuisance, or predatory, ones alike. The proper care of sea stars has long been an area of the hobby in need of improvement. It pains me to see fellow aquarists innocently add these animals to variously themed tanks with hardly a thought for what these creatures eat or need to survive. Many folks assume that "starfish" are simply deposit feeders that will somehow find what they need by grazing about the tank. In fact, very few sea stars can live wholly on the incidental matter that grows or collects in aquarium systems. Moreover, very few aquariums are even capable of growing enough food matter, by weight, to sustain even a single Asteroid (more about classes and groups below). In traditional "garden reef keeping," most of us strive to limit nutrients and nuisance algae by underfeeding and the use of skimmers, other grazers (such as *Turbo* snails, tangs, and urchins) and the cultivation of dominating coralline algae species. This tends to produce "lean" rocks and sand without much soft matter for a sea star to graze upon. In aquariums where suitable food matter does grow for surface-grazing sea stars, insufficient surface area, and hence food, per starfish is oftentimes a limiting factor. Undersized aquaria or overstocked tanks will not produce an adequate supply of potential food matter. The sobering reality about sea stars is that many slowly starve to death within a couple of years, if not mere months, of importation. Making the matter worse, a significant number of collected stars do not survive the importation process to reach a consumer's tank. To be clear, I do not mean to criticize the keeping of sea stars at large. Rather, it is my intent is to acquaint fellow aquarists with some potentially surprising realities about the collection, handling and keeping of these fascinating animals with hope for a more conscientious and responsible use of this group.

The beautiful Blue *Linckia* sea star is perhaps the best known and most popular and sought after variety. They have rather poor rates of survival with aquarists. Most folks tend to do quite poorly with individuals of this species, exacerbated by sensitivities in shipping and handling. For best success, buy these creatures only on sight and after at least five days of acclimation (stabilization) to a dealer's tank. After that, it is advisable to stock them in mature aquaria with aged live rock and few other grazing fishes or deposit feeding invertebrates. A good rule of thumb is a maximum of one *Linckia laevigata* per 100 gallons.

Ask yourself when making decisions, particularly about unfamiliar or notorious livestock for your aquarium, "Do I have an adequate understanding of its needs?" Are you likely to succeed in keeping it for its potential natural lifespan? Do you currently have the means (adequate tank size, age and continuous food source) for keeping it, and not merely the hope of improvement, such as a bigger tank, one day? There are other ways to contemplate such purchases; such as, "Is my purchase a conscientious use of this animal?"

Now the definition of what is conscientious use is, to some extent, subjective. But without hiding behind the guise of an infinite amount of "what ifs" or superlative claims and demands, we should be able to agree on the fundamentals, much like the citizens in a commonwealth collectively agree on laws that are "reasonable" to the majority of a given constituency, which all obey for the greater good. Let us simply begin then by addressing that which we could agree is sustainable harvest, from the perspective of empathetic aquarists that regard the life in our tanks as something more than a mere commodity.

At least several species of sea star (including common *Protoreaster* species), from both tropical and temperate waters, are imported under the common name 'Chocolate Chip Starfish.' They tend to be categorically risky as predators in the long term for tanks with mixed reef invertebrates. They often suffer severe rates of mortality upon importation. It is their low price that perhaps contributes most to the continued popularity of, and tolerance for, these varieties, despite their dubious behavior and suitability for casual keeping in community tanks.

To sum up my position from the start: I believe that an excess of sea stars die between point of collection and final destination of importation, and that too many sea stars successfully imported die within a year of entry to the trade. The reasons for the latter are exacerbated by aquarists who keep these (really, ***any***) creatures casually without: 1) understanding their needs, 2) offering specialized care and 3) adequately target feeding. All of these challenges are sometimes easily overcome with responsible investigation ***before*** making a purchase. Start by finding out where exactly does the animal come from on the reef - hard or soft substrates? Some starfishes' feeding preferences are remarkably challenging, as with feather or basket stars filter-feeding on plankton. They may require very specific plankters and even specific types of water flow to have adequate feeding opportunities. Other stars forage around sand, mud and silt for their sustenance and may fare poorly on hard substrates like typical reef aquariums. Other systems with healthy deep sand beds and refugiums that support large worm populations may find certain starfish prosper in concert. Hmmm... let us also not forget the predatory feeding habits of *Ophiarachna incrassata*, the infamous Green Brittle Star that sits with a fishing pole and drinks beer while listening to country music. Indeed, the feeding habits of "starfish" at large vary widely and it is imperative that aquarists understand their specific animal's needs in advance.

Ophiarachna incrassata, the infamous Green Brittle Star, and a few related kin are the rare exceptions to the otherwise reef-safe and well-behaved Ophiuroid serpent and brittle starfish class. In some tanks *O. incrassata* will behave for months or even years, while in other tanks they tend to catch and kill motile creatures whenever possible They are active predators, which arch their central disk above their legs to form a trap for fishes and other prey. A lurker pictured here.	

Considering the former concern asserted, namely that many sea stars die before reaching consumers, it would be easy to think that we hobbyists have no control here. You do not know the collectors personally, or have a voice in the practices of the airlines transporting the sea life. You do not necessarily know your retailer's sources or have access to a direct line to express your concerns to them. All of this is true. But you ***do*** have the ultimate power over all in the trade of any consumer good, be it stereos or starfishes: your buying decision! Our aquarium hobby and trade, like most any act of commerce, obeys currency. If you stop buying it, they will stop selling it... whoever 'they' are. And so, the case I put forth to you is that with so many other hardy and beautiful creatures available, why use any species of dubious value or questionable sustainability?

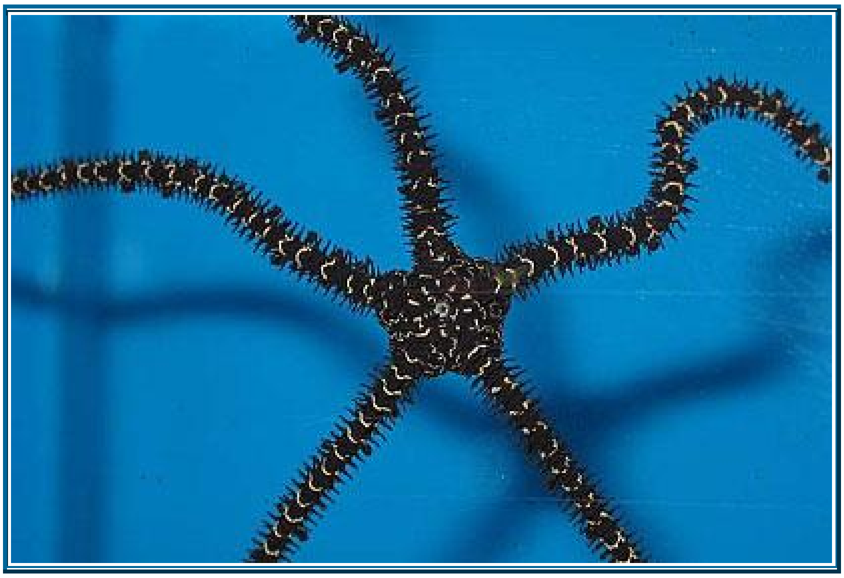
For example, the sale of live "feeder starfish" as prey for the beautiful *Hymenocera* Harlequin shrimp is not uncommon. This shrimp has long been believed, at least in popular literature, to feed only on the tube-feet of certain sea stars. As an aside, they have been observed, anecdotally but often, to actually feed on other echinoderms and other parts of these various animals. Within the genus *Asterina* are one or more species of stars that are prolific in reef aquaria. They usually appear accidentally and have been cultured by aquarists to feed Harlequin shrimp as an alternative to wild-harvested sea stars. Merchants and aquarists may not know of, or may choose to ignore, these other options, though, and rationalize the sacrifice of wild-caught specimens with a claim of light usage, of say - one large wild-caught star per month. The popular imports, however, suffer remarkably high morbidity and mortality just to funnel one healthy live starfish down to the merchant. So we must ask ourselves, how many specimens can be permissibly sacrificed in transit to successfully fill one order: one, two, ten, or more? None need be sacrificed, in my opinion, when *Asterina* is an easy and available home-grown alternative. Even if such options did not exist, we still would have to practice responsible use of wild-caught species. Losing several dozen collected stars annually to provide one live one per month as a "feeder" is not conscientious from my perspective. In such matters, let us not forget the hard lessons learned by our fellow aquarists in Europe: if you do not adequately police yourself, someone else will do it for you! And it should not take government or legislation to get us to make sensible, if not empathetic, buying decisions like this.

Although sea stars like the aforementioned blue *Linckia* and this Purple *Leiaster* (pictured here), have shared reputations for their gross similar appearance, the reality is that their survivability often differs substantially. Because this purple species is far less common in the trade, and therefore more valuable, they tend to get handled better with larger bags and more water in transit. Subsequently, they may enjoy higher rates of successful establishment in captivity. Aquarists should use such insight to strategically select species that are better choices in the long run for both themselves and the hobby.

The following evaluations of sea star species or varieties as "favorable/best of," or "unfavorable/worst of," take into consideration a wide variety of issues. Some potentially excellent aquarium species can make the "worst of" list because of present shipping realities (strategically poor sources of origin - unavoidably extended duration of transit, poorly funded or prepared collection communities, etc.). Putting aside my own reservations about "rules of thumb" or gross generalizations, I offer the following categorizations of the classes of sea stars, which I believe are fair and accurate:

Common and so-called "fancy" Ophiuroids like this banded species are available from Florida. They are hardy, ship well and live long once established with modest but faithful husbandry. Feed small amounts of mixed green and meaty foods several times weekly. A fine scavenger for beginners and newer aquaria that are regularly fed.

Ophiuroids - Serpent Stars: with the exception of basket stars (see overview of Crinoid feather stars below as similarly challenging), the majority of serpent and brittle stars are hardy and suitable for home aquarium life. Many will fare well even in smaller aquariums (under 20 gallons), provided that they are target fed at least weekly. Most are harmless, if not helpful, in reef displays as innocuous bio-turbators (sand-stirrers), eating particulate matter or at least keeping it in motion or suspension for nutrient export processes such as skimmers and mechanical filters. They are the least discriminating and most adaptable feeders of all "starfish." Unlike other popular clean-up creatures (hermit crabs, perhaps most notoriously), Ophiuroids are only a light burden on the bio-load and bio-diversity of the system. Numerous species in this class are suitable for beginners. Species native to tropical Florida waters are highly recommended for aquarists for their utility and ease with which they can be successfully collected and shipped to aquarists in the United States - short transit time, frequent direct flights to distributors, and hardy by nature once established.



Even ornate Ophiuroids tend to be hardy and long-lived once established in reef aquaria. They enjoy rocky habitats and will usually accept a wide variety of foods.

Crinoid - Feather Stars and Sea Lilies: there is very little to discuss here regarding this extremely challenging class of organisms. I won't even pay lip service to the noble charge, "If an advanced aquarist works hard enough and sets up a species-specific system just for [Crinoids], there is a chance of success." Point blank: please do not keep or encourage others to keep these creatures at this time. Why? You may ask. It's a fair question, indeed. Sadly, the overwhelming majority of specimens will perish within weeks or months of collection. They are notoriously delicate and weak shippers. Their dietary needs are poorly understood and difficult, if even possible, to meet in aquarium systems (i.e., steady supplies of enough of the right kind and quantity of plankton, bacteria, etc.). The few specimens out of hundreds that do survive six months or more in captivity simply do not justify the collection of so many others, which die to pave the way for the arrival of each live one. This is one of those groups of reef creatures for whom we must step forward and make a conscientious choice not to support the collection of for casual keeping or impulse purchases. To any aquarist that disagrees with this position, I respectfully ask him to soberly consider the effect that the promotion of keeping such species to the masses does, and to kindly document, if possible, any unique successes of several years or more with Crinoids, rather than simply reporting specimens that took 6, 12 or 18 months before finally starving to death.

Asteroid Sea Stars - classic body "Starfish": without stepping down completely from the anti-Crinoid and anti-Basket Star soapbox, I come to perhaps the most underestimated class of sea stars, the Asteroids. While many aquarists will agree that Ophiuroids are generally hardy and easy to keep, and that Crinoids are difficult to keep, the classic Asteroid "starfish" species are largely mishandled and often suffer very badly for it. Species from this class often carry the erroneous reputation of being good scavengers (like *Linckia* species) that magically live off of whatever organic film happens to be growing in the aquarium, assuming that beer nuts and salty pretzels are not available to eat instead. Unfortunately, some are so remarkably inexpensive to import for sale that consumers can buy one weak and dying specimen after another with little incentive (beyond ethics) to stop and consider the suitability of the species or source for aquarium use. Alas, this class includes many of the most beautiful sea stars known to man. All is not doom and gloom, however, for keeping Asteroids. Unlike filter-feeding crinoid and basket stars, most of the difficult Asteroid species are not inherently challenging to keep alive. Given an appropriately constructed set of physical parameters in the aquarium, and a healthy import, many Asteroids can be kept with relatively little effort. They do, however, require specific care. Most are carnivorous and target specific prey that may not exist or be adequately produced in aquaria to sustain them (particularly smaller aquaria). Most species in this group are not "reef safe."

A small but steady stream of larger, novelty Asteroid sea stars seems to always trickle into our hobby. Some of these pillow, pincushion and bat stars for example are highly predatory, require uncommon amounts and frequencies of food, and are generally unsuitable for any but the absolute largest home aquaria (over 300 gallons), like this temperate cnidarian predator, *Dermasterias imbricata*.

It's easy to underestimate the need for small frequent feedings (three to five times weekly) in a sea star's diet. It's even easier to underestimate the need to target feed these creatures at all. We must consider the not-insignificant size/weight of a medium sized "Chocolate Chip," "Red African," or Blue *Linckia* starfish, for example, which is many times the mass of some popular reef fishes that eat routinely. The size of these animals also causes serious problems without proper quarantine (QT) when a sick or dying specimen crawls into an inaccessible crevice of the rockscape and begins to decay. It's not hard to imagine what a comparable mass, like a 4 oz. package of frozen meat or a large can of food pellets, poured into the tank and left to rot would do to water quality in mere hours. QT is not only for disease control, but also for screening for incidental pests and predators carried in (flatworms or predatory snails, for example) and the simple, controlled acclimation of stressed, newly imported specimens under close supervision.

We should also take some time to consider what is "reef-safe" among new candidates. To anyone with more than just a little experience as an aquarist, the reality of what defines "reef-safe" is better-appreciated. Ultimately, there is no such organism from a wild reef, for display in your reef tank that is purely "reef-safe." Put another way, everything on a reef eats something else on the reef! Thus, the definition of whether a given organism is "safe" or not for your tank truly hinges upon whether or not you personally like or dislike whatever it eats. To illustrate this point, to the aquarist with a dreadful nuisance algae problem, an urchin mowing through the tank eating hair-, macro-, and coralline algae is like is a blessing. To another aquarist without hair algae, simply losing his corallines or desirable macros to the urchin, the grazer may be deemed "not safe."

Asterina sea stars have been accused, unfairly at times, for preying on coral tissue. While some individuals appear to eat some desirable reef invertebrates, the problem may be a simple matter of an opportunistic predator adapting to a change in the available, preferred foods (worms, algae).

Returning to our example of the common, small *Asterina* species found in some reef tanks, these sea stars in recent years have suffered, unfairly I might add, the reputation of being risky or just plain un-safe in the reef. This is interesting because for many years prior to that, they were not only regarded as harmless, but beneficial! What happened? Did they all change their voter registrations overnight? No, the answer really is quite simple. It also explains why some other "controversial" reef invertebrates have contradictory reputations like *Mithrax/Mithraculus* crabs. Many such creatures are opportunistic feeders. While they favor one type of prey that is convenient or popular to us, like sand bed worms, brown diatoms or bubble algae, they will adapt to eating other food items following the reduction or absence of a preferred food item. Thus, the reef keeper with a persistent growth of microalgae in a garden reef display will likely have less trouble with misbehaving omnivores than another aquarist with an aggressively skimmed and scrubbed tank that supports little growth of the matter. In a phrase, the hungrier that a so-called "reef-safe" creature gets, the less "reef-safe" that creature becomes. In the case of *Asterina*, many years ago during the bare-bottomed, nutrient poor Berlin style era of reef keeping, reef husbandry with early protein skimmers and limited nutrient export processes was not as efficient as it is today; diatoms and other nutritious growths grew quickly in our tanks. And *Asterina* were not considered un-safe by hobbyists.

Summary of Keys to Success with Sea Stars:

- Identify the species, needs and suitability of a candidate ***before*** purchasing. Know the natural habits and habitat (soft substrates, hard substrates, opportunistic feeder, carnivore, etc.).
- Be strategic on selection: avoid impulse purchases, seek Ophiuroids among the most suitable stars. Avoid Crinoids, and resist keeping Asteroids casually or in young or smaller aquaria (less than 1 year old or <100

gallons per sea star).

- Quarantine all new acquisitions to screen for possible pests and predators, to acclimate and stabilize newly imported specimens in the confines of close quarters, and to concentrate feeding opportunities to establish a stronger specimen, spare the display from serious risks to water quality in case of a weak specimen dying in the recesses of the rockscape.
- Target feed most species several times weekly (smaller, more frequent feedings are always best).

In conclusion, I simply wish to re-emphasize that most starfish we encounter in the aquarium trade are not so opportunistic, if even opportunistic at all, as to be able to survive in aquaria without special attention paid to their feeding and other husbandry requirements. By isolating new acquisitions, addressing special requirements, and not underestimating the needs and merits of keeping starfish in marine aquaria, we can significantly improve rates of survival and success with these fascinating creatures.

If you have any questions about this article, please visit my author **forum** on Reef Central.

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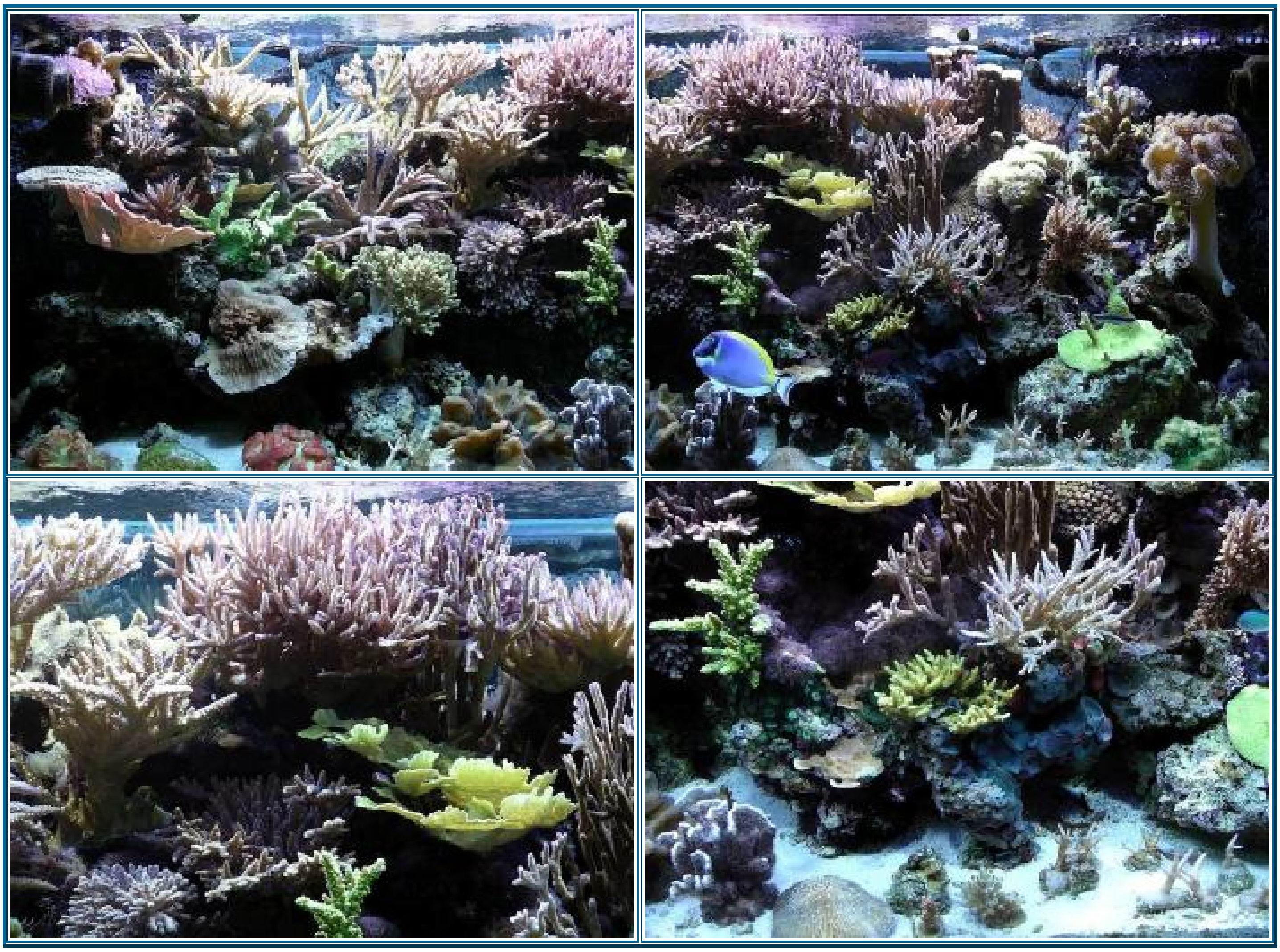
Tank of the Month

June 2004

Andy Bajc's (Andy) Reef Aquarium

Introduction and Background

First, I'd like to say how grateful I am for being selected for *Reefkeeping Magazine's* Tank of the Month. Reef Central and *Reefkeeping Magazine* have featured some of the most beautiful tanks in the world and although I don't consider my system to be in the same league as many of them, I do consider it a great honor to be featured among them. Being situated in a small northern Ontario city, I can't overemphasize the importance of sites like Reef Central in providing a tremendous resource for learning about this wonderful hobby. I can certainly attribute a large part of my success directly to the advice and experiences I have mined from the Reef Central forums.



My interest in marine aquaria began in 1997 following a protracted fascination with African cichlids that lasted well over ten years. The transition from freshwater to marine came with challenges, as I reef dominated by LPS, soft corals and a large fish population. An undergravel filter supplemented with a canister, biowheel, fluidized bed and carbon tube filtration systems proved effective in the short term but eventually resulted in unmanageable nitrate levels. Overcrowding-induced stress caused frequent outbreaks of Ich among the fishes. I treated this temporarily using UV sterilization and potions marketed for their magical abilities to cure various ailments. Unfortunately, it was only through trial and error and thousands of dollars invested in equipment, much of which currently resides in storage containers, that I acquired the basic skills required to keep a successful reef ecosystem.

Aquarium Profile:

- **Tank:** 280-gallon eurobraced Inter-American tank (72" X 30" X 30") with corner overflows and 2" Durso stand pipe drains
- **Sump:** 70-gallon Inter-American sump (48" X 18" X 19")
- **Stand & Canopy:** 2" tubular steel stand enclosed by custom built cabinet with matching 12" high hood (Aquaview Industries)

Aquarium Profile

In the spring of 2001, plans were underway for an upgrade to a larger, 280 gallon system. Space-wise, I was limited to the same 72" of tank length as the previous setup but had the luxury of expanding to 30" of both width and depth. My interests had shifted, as occurs with most hobbyists, from common LPS and softies to more light and/or flow-demanding SPS corals and clams. My new system would require some significant design changes and although the final tank layout still has a number of inherent deficiencies, it has proven effective for the successful husbandry of the animals I currently keep. In this article, I will highlight some of the main elements of my setup. As we all know, there are many ways to do things in this hobby. I hope that by sharing my experiences, I can help others as they strive for success. I welcome comments and hope this review fosters discussion.

The transition to the new system was complicated by the fact that the tank would reside in the same location as the old one. That meant I would have to tear down the old setup and house the live rock and corals I planned to keep in temporary holding tanks during the transition period. In September 2001, I dismantled the old tank and began construction of the new system. The complete new system was installed and cycled by mid-December.

I purchased my tank from Inter-American Pet Supply in Calgary, Alberta and was very pleased with the quality of their workmanship. The tank is eurobraced and has two back corner overflows, each containing a 2" Durso standpipe drain and 3/4" return. The tank weighs 800 pounds empty and if it weren't for hired piano movers, it would have been a real challenge to get it into position in my family room. The tank has 5/8" thick LOF glass walls, a 3/4" thick glass bottom, is laminated with an Indicoat mirror backing, and contains greylite glass overflows, black silicone seals and ground and polished corners.

The tank sits on a custom-built Aquaview Industries stand manufactured in Toronto. A two-inch tubular steel frame sits inside the stand to provide the necessary strength to carry the tank's two-ton load. A 12" high matching canopy built by the same company houses the lighting system.

A 70 gallon sump, subdivided into three main compartments and containing a series of baffles to prevent bubbles from returning into the show tank, sits under the tank in the stand. Two 3/4" bulkheads plumbed to Gen-X Mak 4 return pumps in the adjacent room push tank water back to the tank through 3/4" Loc-Line spouts split to two 1/2" flared nozzles. Two Maxijet 1200 pumps provide additional flow along the back wall of the tank. The sump holds a My Reef® Creations protein skimmer and receives effluent from the Precision Marine calcium reactor and Reef Solutions kalkwasser reactor.

Circulation and Filtration

A Tunze Turbelle stream TS/24 kit provides the majority of the system's flow. I have placed the two powerheads at opposite ends of the tank, pointing at each other and set to pulse between 65 and

100% flow at a five second interval. Since adding the streams, I have noticed a marked improvement in both coral health and growth rate. Polyp extension is significantly better and detritus build up on the live rock is significantly less.

Circulation Equipment:

- Tunze Turbelle Stream TS/24 kit
- Two Maxijet 1200 powerheads
- Two Gen-X Mak 4 return pumps

Filtration Equipment:

- Mechanical filtration using white floss pads in sump
- My Reef Creations® dual-injected MR-3 in-sump protein skimmer with waste collector (currently running one Beckett injector with a Mag 24 pump)
- Marineland Black Diamond activated carbon is run passively in sump

Water Conditioning Details:

- RO/DI water (SpectraPure 3 stage reverse osmosis unit)
- Dual TDS meter to monitor water quality
- Instant Ocean synthetic sea salt
- ReefFiller dosing pump running 24/7 through Reef Solutions kalkwasser reactor (Two Little Fishies kalkwasser)
- Precision Marine CR422 calcium reactor using CaribSea ARM reactor media

Lighting and Environmental Control

For 6.5 of the 7 years I have been in the marine hobby, I have lit my tanks with VHO fluorescent bulbs. It wasn't until December of 2003 that I switched to a metal halide/VHO combination. I currently light this tank with a do-it-yourself setup comprising three 400 watt Radiums fired by Son Agro 430 watt high-pressure sodium ballasts and two 60" URI VHO fluorescent actinic bulbs driven by an IceCap 660 ballast. I am also running a 48" T5 fluorescent actinic bulb driven by a Workhorse 7 ballast. I transitioned from VHO to this combination over a ten-week period by slowly increasing the metal halide's photoperiod by an hour per week and simultaneously reducing the VHO cycle by the same amount.

The immediate response to this lighting change was the bleaching of most of the coralline algae in the well-lit areas. A decrease in ORP from 425 mV to 350 mV also corresponded with the change. I assume this signaled a dramatic die-off of various life forms not adapted to intense light environs. The ORP of the tank has slowly climbed back to the range of 400-425 mV. Coralline algae growth has resumed, albeit at a much reduced rate, and thrives only in caves, overhangs and lower levels of the tank.

Temperature Control:

- Two 250-watt Ebo-Jager heaters
- 1/2 hp Pacific Coast Chiller driven by a Mag 9.5 pump

Photoperiod Timing:

- Actinics on at 9:00 am, off at 11:30 pm
- Metal halides on at 11:30 am, off at 9:30 pm

Heat was a real concern I had with the transition. Four IceCap fans, mounted inside the canopy, help to disperse heat and cool the stainless steel reflector. A 1/2 hp Pacific Coast chiller plumbed inline with the sump generally runs during the metal halide photoperiod and easily handles the residual heat. The metal halide ballasts sit in a room adjacent to the tank with the chiller, return pumps, dosing pump, kalkwasser reactor and make-up water reservoir, further alleviating any potential sources of additional heat. Details of the lighting system are highlighted below.

Lighting System Details:

- 3 x 400-watt radium MH bulbs driven by son agro 430-watt HPS ballasts
- 2 x 60" 140-watt URI VHO actinics driven by IceCap 660 ballast
- 1 x 48" T5 actinic bulb driven by Workhorse 7 ballast
- 70" high-polish stainless steel reflector

Water Parameters

The water parameters that I regularly monitor include temperature and ORP, and only occasionally specific gravity, calcium and alkalinity. I have learned to read my tank's water quality by the behavior of its occupants. I used to sweat pH to no end but now feel that daily swings between 7.9 and 8.2 don't adversely affects the tank's inhabitants. On many occasions, the presence of a dozen or more people in my family room has caused a huge spike in CO_2 and an associated drop in pH of 0.2-0.3 pH units over a 3-4 hour period. In all cases, the tank responded as if nothing were amiss.

Water Parameters:

- **Temperature:** 78-80°F
- **pH:** 8.1-8.3 (Pinpoint pH monitor)
- **ORP:**400-425 mV (Pinpoint ORP monitor)
- **Calcium:** 400-450 ppm (Red Sea kit)
- **Alkalinity:** 10 dKH (Aquarium Pharmaceuticals kit)
- **Magnesium:** 1335 ppm (Salifert kit)
- **Specific Gravity:** 1.024 g/cc (Pinpoint salinity monitor)
- **Ammonia and Nitrite:** below detection (Red Sea kit)
- **Phosphate:** below detection (Red Sea kit)

Maintenance

Maintenance:

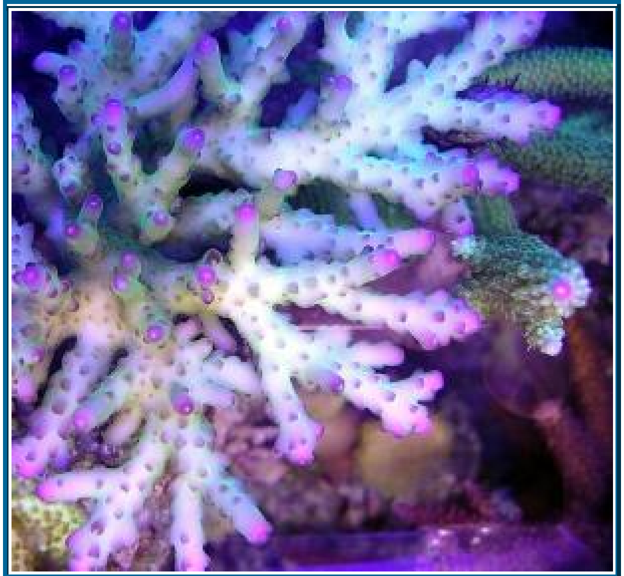
- 10% monthly water change
- Skimmer cleaned weekly
- White filter floss changed biweekly
- Kalkwasser reactor topped weekly with 3 heaping tablespoons kalkwasser

My occupation as a geologist takes me away from home on many occasions throughout the year. My sojourns often last two to three weeks, especially during the summer. I had to keep this “small" point in mind when designing my system. I don't think I would be too popular with my wife if she had to top off, dose, feed, perform water changes, etc. on a regular basis. For this reason, I have automated as many tank functions as possible. Top-off is performed by a ReefFiller dosing pump. Calcium and alkalinity are maintained by a Precision Marine calcium reactor and Reef Solutions kalkwasser reactor. Water quality is maintained with a My Reef Creations® MR-3 protein skimmer, which is pretty much set and forget if the sump's water level is kept constant. That leaves a quick check of a few vital parameters, and feeding, as the only daily tasks. Below is a list of the regular maintenance items I perform on the tank.

- Calcium and alkalinity levels checked monthly
- Sump water level, protein skimmer operation, calcium reactor drip rate and CO_2 bubble count, temperature and ORP checked daily
- Front glass cleaned daily


Tank Inhabitants

My tank contains several hundred pounds of Fiji, Great Barrier Reef, Tonga branch and Tonga plate live rock, some of which I have had since 1997. A large portion of the rock has been permanently fused together by some of my encrusting corals such as *Porites* sp. and *Leptoseris* spp., which have spread from one rock to another.



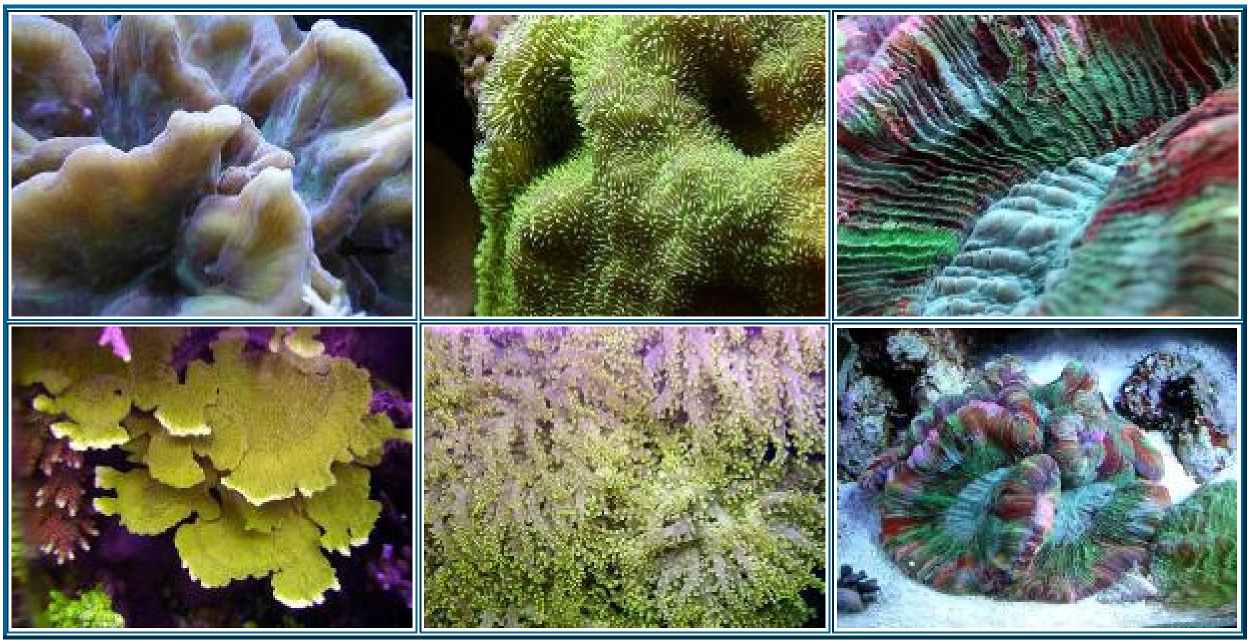
When I was setting up this tank, deep sand beds were just becoming popular. I opted for a more traditional shallow sand bed (1-2 inches) composed of CaribSea “select grade" aragonite. I prefer the look of a shallow sand bed, and believe I can achieve effective denitrification with a large amount of dense, chunky live rock. A sand-sifting starfish and several sea cucumbers keep the sand bed stirred.

My fish population has stood at 11 for the last year or so. Before that, I had a number of others including a Sunburst anthias, Yellow-headed jawfish and Swissguard basslet whose disappearance from the tank remains a mystery. My Six-line wrasse and Potters wrasse both have an affinity for the overflows, and have jumped into (and back out of) them on several occasions. I hesitate to add more fish now because the current group gets along so well. I would love to have a small school of Bartlett's or Purple Queen anthias in my tank, but I think their demanding dietary requirements would negatively impact my system.

Fish:	
1 Powder Blue Tang	1 Six-Line Wrasse
1 Potters wrasse	1 Cleaner Wrasse
6 Green *Chromis*	1 Purple Firefish
1 Royal Gramma	

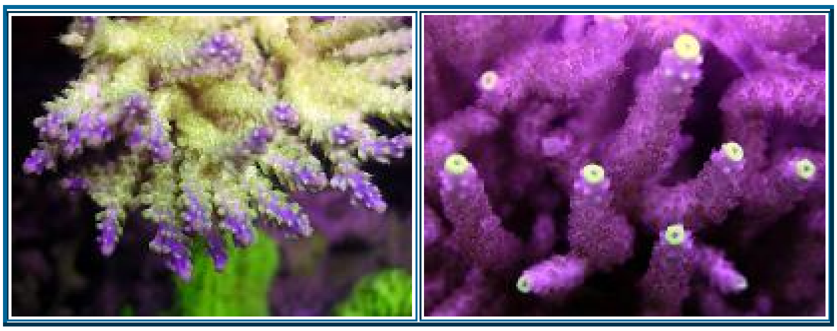
Invertebrates:	
1 Sand-sifting starfish	4 Blood Shrimp
3 Sea Cucumbers	Blue-legged hermit crabs
Commensal crabs in various *Acropora* colonies	*Turbo* and *Astrea* snails
3 *Tridacna crocea* clams	1 *Tridacna maxima* clam

Corals:	
Anthelia sp.	*Capnella* sp. (Kenya tree coral)
Erythropodium sp. (encrusting gorgonian)	*Heliopora coerulea* (blue ridge coral)
Pachyclavularia sp. (green star polyps)	*Sarcophyton* sp. (toadstool)
Sinularia sp. (finger leather)	*Xenia* sp.
Protopalythoa sp.	*Zoanthus* sp.
Actinodiscus spp. (blue, green, green stripe, red, brown, speckled, marble mushrooms)	*Discosoma* sp. (bubble or warty mushroom)
Ricordea sp.	*Anthelia* sp.
Acropora spp. (at least 25 species)	*Blastomussa* sp.
Caulastrea furcata	*Echinophyllia* sp
Euphyllia sp.	*Fungia* spp.
Galaxea sp.	*Hydnophora* sp.
Leptoseris spp.	*Merulina ampliata*
Montipora digitata (purple tip, orange)	*Montipora capricornis* (red, green, brown with blue polyps)
Pocillopora damicornis (pink)	*Porites cylindrica*
Pachyseris rugosa	*Pavona* sp.
Pectinia sp.	*Scolymia* sp.
Stylophora pistillata	*Trachyphyllia* spp.
Turbinaria spp.	



Feeding

I used to believe in a heavy feeding regimen but have now reversed that trend and feed sparingly. I now feed either once every day or every other day. The tank is so heavily stocked with corals that it is very sensitive to excessive nutrients. I have lived through horrendous cyanobacteria, dinoflagellate and hair algae blooms in my previous tank and will do everything possible to prevent them in this system. Despite limited feeding, the Powder Blue Tang continues to look fat and healthy. Being one of my more sensitive fish, I figure he would be the first to show signs of malnutrition. His constant grazing on the rocks is undoubtedly providing him with more than enough natural food.

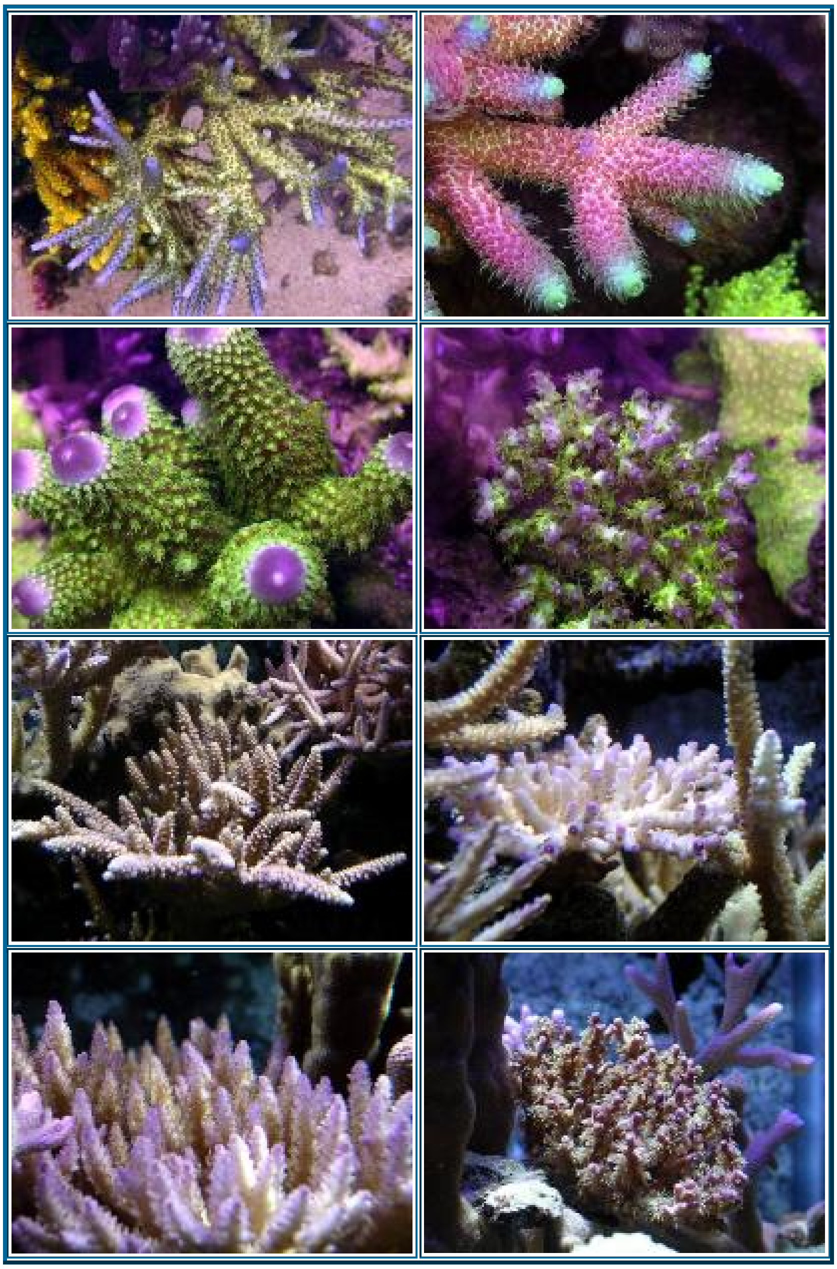


None of the corals is target fed. Weekly additions of either DT's Phytoplankton, Golden Pearls or Cyclop-Eeze, in addition to the flake and meaty foods (including their juices) listed below, provide adequate food for the tank's corals.

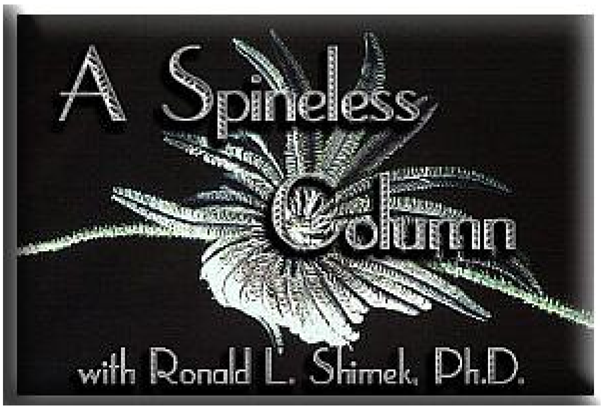
- Ocean Nutrition flake food (Formula One, Two and Prime Reef)
- Omega One marine flakes
- DT's Live Marine Phytoplankton
- Cyclop-Eeze frozen bars
- Golden Pearls Active Spheres Larval Diet
- Piscine Energetics mysis shrimp
- Hikari brine shrimp
- Hikari mysis shrimp
- Hikari krill
- Julian Sprung sea veggies

Concluding Remarks

I'm sure many reef enthusiasts know what I mean when I say this hobby is all-consuming and offers tremendous rewards. It has given me great pleasure to share my system with the reefkeeping community. I thank the staff of Reefkeeping Magazine and Reef Central for allowing me to do so and look forward to seeing future Tanks of the Month featured on this wonderful site.



Feel free to comment or ask questions about my tank in the Tank of the Month thread on Reef Central.



The Grazing Snails, Part II - Abalones, Limpets and Nerites

Introduction:

In last month's column I wrote about the group of snails generally referred to in the aquarium hobby as "Turbo Grazers." Commonly called "top" or "turban" snails these animals are fundamentally similar in shape and in natural history. In this column, I will be discussing other algae-eating snails, specifically the Abalones, Limpets, and Nerites. Unlike the trochoideans, these animals are not closely related and don't form a nice, coherent group with common characters. Rather, they are from several distinct evolutionary lineages. Their generalized internal anatomy and physiology, however, are the same as in the trochoideans, and I refer the reader to May's column if there are questions about the animals' basic needs and the necessity of slow acclimation to differing conditions, particularly salinity. Feeding in these animals follows the basic invertebrate pattern; the animals "lick" the surface of the substrate with a structure which has been called a "rasping tongue," and which biologists call a "radula." On the other hand, while there are similarities in feeding between all of these various groups, there are also differences. The number and shapes of radular teeth as well as, in some cases, their compositions vary between these groups and are different from the trochoideans as well.

The gastropods, or snails, constitute a huge array of species; there are well over 40,000 named snail species and estimates of species numbers range up to 150,000. The number of actual species may be significantly fewer than that, but nevertheless that number will still be very large. The soft parts of snails are largely hidden out of sight inside their shells, so consequently, snails are distinguished based on differences in the shapes of their shells. So far, so good; their identification sounds like it should be easy. However, the typical snail shell is basically a long slender cone wound into a helical shape, and that is a simple shape. There are fundamentally very few variations that can be made in this structure. This, in turn, means that identification of species may be very difficult as there are not a lot of differentiating characteristics that can be seen. Given the number of different species, it is highly likely that there is a large number of distinct species with exceedingly similar shell shapes. Consequently, to identify them requires examining characteristics that are often tiny, obscure or uncertain. To further complicate matters, given that the shells are made of calcium carbonate, the identifying characters may simply be worn away or used as a substrate by other encrusting forms inextricably attached to the shell. Additionally, even with shells in the best of condition, it may be impossible to distinguish some species for the simple reason that their shells are identical. In one snail group I worked with, one researcher described two species, one with a radula and one without, but the shells of the two species were about as close to being identical as they could be (Smith, 1967). For these reasons, I generally do not recommend that aquarists try to identify snails to the species level; it is sometimes possible, but for a great many species, it is simply not worth the effort.

Figure 1. An abalone, *Haliotis kamtschatkana*, grazing on some algae. Note the tentacles protruding from the holes in the shells. The head is to the left.

The trochoideans that were the subject of the May column all have a relatively similar appearance. In fact, they are so much alike that most aquarists have problems telling them apart. This ambiguity of identification is an advantage in that it allows collectors to provide us with usable animals without having to be very discerning in their collection. In the aquarium trade, the terms *Turbo*, *Trochus*, and *Astraea* (generally misspelled "Astrea") are all applied to any species of those genera. In other words, if you want to know what Trochacean you have, you are pretty much on your own for identification, because many common names used by dealers are unreliable to the point of uselessness. This is largely immaterial, however, as the animals do tend to have similar requirements and attributes.

Unfortunately, the grazers that are the subject of this column have no such similarity of shape. While the consumption of various types of algae is widespread in the gastropods, the number of those species that are suitable for reef aquaria is really surprisingly small, and with few exceptions there are few similarities in shape to help distinguish them. It is up to the individual hobbyist to be sure of the identification of these beasts. Three references may be of significant help in this regard. As aquarists we can, in this case, benefit from the hobby of shell collecting. Shell collectors greatly outnumber reef aquarists and their hobby supports the publication of many shell identification guides. The following three references, while not written with the aquarium hobbyist in mind, will help with the identification of many mollusks including the snails. They have the added advantage of being in many local public and university or college libraries, and so may be readily available for consultation.

Identification References:

Abbott, R. T. 1974. *American Seashells*. Van Nostrand Reinhold Company. New York. 663 pp. This reference will allow you to make tentative identifications of about 30% to 50% of the Caribbean reef snails.

Abbott, R. T. and S. P. Dance. 1982. *Compendium of Sea Shells, A Color Guide to More than 4,200 of the World's Marine Shells*. E. P. Dutton, Inc. New York. 410 pp. This reference is good for identifying snails from marine environments around the world, but is missing a lot of, mostly smaller, species.

Keen, A. M. 1971. *Sea shells of tropical west America*. Stanford University Press. Palo Alto, Ca. 1064 pp. This reference is excellent for Eastern Pacific and Gulf of California animals, and is good for some other tropical Pacific animals.

Abalone

Abalones, or snails in the genus, *Haliotis*, are some of the classic grazing snails. Unfortunately, they tend to be too large for reef aquaria as some of them reach diameters of eight inches (20 cm) or more. When viewed in profile from the side, abalones are basically wedge-shaped with the sharp point of the wedge at the front end. Many of them are the preferred prey of some very diligent and persistent visually-oriented predators such as fishes, birds and sea mammals, so the snails have been forced to evolve the behavior of hiding from their predators in cracks and crevices where they are difficult to see and even more difficult to remove. Practically speaking, this means that in aquaria, they often tend to push their wedge-shaped shell under rocks or between the larger pieces of rock. With their large broad feet and tough shells they can exert a significant amount of force on the rocks. In nature, where the rocks are part of Mother Earth and don't move, this behavior ensures that the animal is well protected. In an aquarium, such behavior may significantly rearrange a tank. A four or five inch long abalone can easily move and shift rocks weighing twenty pounds (9 kg) or more. Few aquaria can withstand this sort of perturbation, and as a consequence not many aquarists want to deal with abalones.

We are fortunate, however, as not all abalones will cause this rearrangement. One of the best types of grazing snails for cleaning diatoms and other adherent algae from smooth surfaces, such as aquarium walls, is a species of tropical abalone, ***Haliotis asinina***, commonly called "the Ass's ear abalone." The common name comes from its elongate shape, and to someone who may have never seen a donkey's ear, it probably looks like one. Abalone shells are coiled, but they don't really look like it as the coil expands so rapidly that the shell looks almost like the bowl of a spoon, or an ear. In fact, the scientific name, *Haliotis*, means "sea ear." Viewed from the top, the shell can be seen to be in the form of a rapidly expanding coil, with the more pronounced whorls being located at the animal's stern. Additionally, abalone shells may be positively identified by the series of small holes running in a line near the left edge; no other flattened type of snail has such a row of holes. When the animal is grazing, a sensory tentacle will often be seen extending from one or more of these holes. The shell color is typically mottled greens and reds to yellows; good camouflage coloration for a reef animal. Much of this variety of color is the coloration of the shell proper, but a lot of it is due to the growth of various algae on the shell. *Haliotis asinina* reach a maximum size of about four inches (10 cm), but grow slowly in our systems. The ones available for the aquarium trade are generally from **aquacultured stock** and are often about one to 1.0 - 1.5 inches (2 - 3 cm) long. One specific caution is necessary for their care: they need to be acclimated very slowly to salinity changes, and it is best to err on the side of caution. As with other snails, they use their **radula** (scroll down on the linked site) to graze. Generally, they prefer to graze on glass, and often will not go on the rocks at all. They are nocturnally active and often will seek a dark space in which to pass the brightly lit hours. Often, they will return to the same "home" space for many months.

Limpets

The generalized limpet body form is that of a snail bearing a conical, uncoiled cap-shaped shell and possessing a broad foot. This type of morphology is found in a number of snail groups that are only distantly related. Consequently, it is difficult to generalize about or predict the behavior of any particular limpet species. The limpet shape is well adapted to withstand wave stress and the pounding surf, and most limpets are animals of the intertidal regions. Intertidal tropical limpets are common, and are quite good grazers, but they are not good reef tank inhabitants as they tend to climb out of the tank. Often they climb up and out of the tank and then fasten themselves down, presumably to wait for high tide; which, of course, never comes. This results in the death of the limpet and the concurrent creation of limpet jerky.

There are a number of types of **subtidal limpets** occasionally available for the coral reef aquarium. Generally, they are not particularly good animals to have in aquaria. Those shallow water forms that graze on algae seem to have a decided tendency to eat coralline algae. These limpets are exceptionally well equipped to eat these algae. They have a **radula** with teeth made of a mixture of iron salts (primarily hematite) and silica (in the form of opal). This gives them a rasping organ with a value of 7 or 8 on the Mohs scale of mineral hardness. Additionally, the opal is deposited in the teeth as small inclusions that tend to abrade away slightly faster than does the hematite. This turns the tooth into a self-sharpening rasp; the more it is used, the sharper it becomes until the tooth abrades away completely and another replaces it. The limpets possessing such a rasping apparatus can cut through and remove coralline algae like it was butter, and some of them can do the same to acrylic aquarium walls. Unlike sea urchins, which typically eat a small patch of algae and move off some distance until they feed again at some later time, the **limpets are pretty much constant grazers**. There are some other species of small limpets, occasionally available from some vendors, which are relatively benign and good grazers on microalgae. Unfortunately, these species are seldom offered for sale even though at least some of them appear to reproduce in captivity. It is essentially impossible for a novice to distinguish between these species as some of the identifying characteristics are on the internal surface of the shell, so one has to have a dead shell to examine to determine the identity of the animals. Unless the vendor can vouch for the dietary preferences of the animal that he is selling, it might be best to pass by limpets on the way to the checkout counter.

Additionally, there are some limpets that generally do not graze on algae. The ones that we are primarily concerned about are the **keyhole** and slit limpets. These are limpet-shaped snails with a perforation on the top of the shell (keyhole limpets) or a slit on the front shell margins (slit limpets). These animals are generally carnivorous, and will eat sponges, soft corals, and other sessile animals. I have not heard of any specific reports of them eating stony corals, but I suspect that they would. Some of them, however, may be very useful for the control of some low growing colonial nuisance hydroids. Unfortunately, little work has investigated the specific diets of tropical keyhole limpets, so we don't know the names of any beneficial species. Consequently, unless you are willing to put up with some predation on coralline algae or some of the animals in your system, I would leave most limpets to the sea.

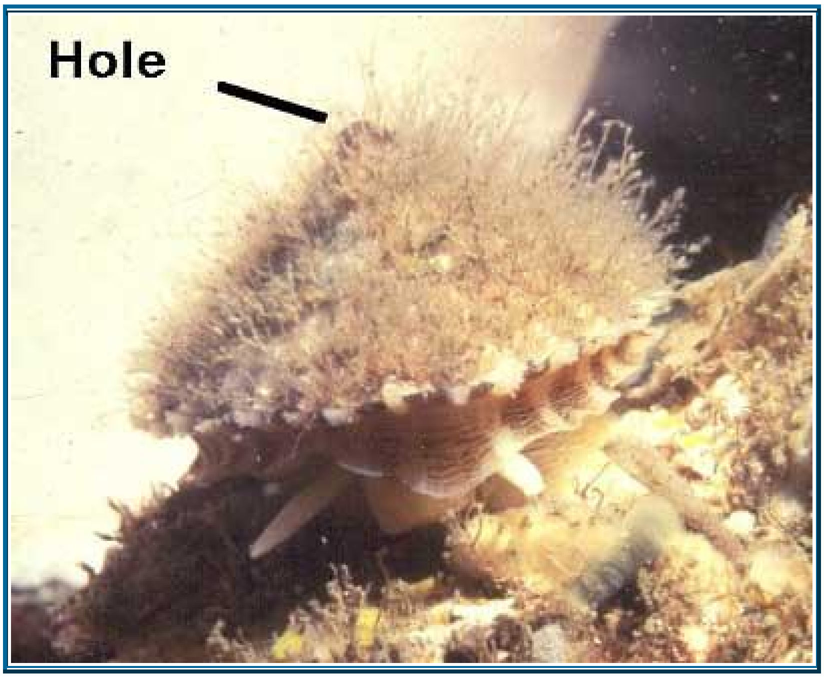


Figure 2. A keyhole limpet, *Diodora aspera*. The fuzz on the limpet shell is comprised of hydrozoans, and they are probably as safe as they can be anywhere in the vicinity of the limpet since it can't feed on them up there.

Two types of limpets that appear to be not only beneficial, but attractive, are ones that really don't look like limpets. These are the shield limpets and fleshy limpets. When fully active neither of these types of animals has much of a resemblance to the common limpets, but both are related to them. Both of them have a large fleshy structure, the mantle, which extends up over the shell and largely obscures it; in essence the animal looks like some kind of slug or nudibranch.

Shield limpets, ***Scutus unguis***, are commonly collected on Indo-Pacific live rock. They may reach lengths of an inch or a bit larger (up to about 3 cm). Most of the size is due to the fleshy black mantle that covers the shell. These animals are nocturnal and will hide under and between rocks during the day. At night they come out to graze on microalgae such as diatoms on the rocks. They appear to be blackish blobs, although the white shell can often be seen peeking through the folds of the mantle covering the animal. If disturbed so that the animal retracts the mantle, the ordinarily appearing limpet **shell** will be seen attached to a rather large body. These are good grazers, and are quite beneficial animals to have in a reef tank. Unfortunately, they don't seem to reproduce in reef tanks, and generally don't seem to persist for more than a few months.

Fleshy limpets, ***Lucapina*** species, are commonly found on Caribbean rock, and there are several species of them. The largest are about the size of shield limpets, but many are smaller. They also have a mantle that extends up over the shell, but in this case, the **mantle is brightly colored** and ranges from yellow to red. These are keyhole limpets, and as such are probably omnivorous, but from the reports I have received, they don't seem to be eating the decorative livestock. Generally, they seem to be grazing on algae. Like the shield limpets, they are largely nocturnal and are generally out of sight and inactive during the day. When the mantle is retracted, they will be seen to have a small shell on their back and its center will be perforated with a hole. As with the shield limpets, they don't appear to reproduce in aquaria and generally only survive a few months.

Nerites

Numerous species belonging to the genus ***Nerita*** make good herbivores for many reef tanks. These snails are recognized by the rounded shell which, although it is coiled, has a low spire. The aperture from which the body extends is basically "D-shaped" with several large calcareous bumps on the inner edge. The outer edge is also often marked by similar calcareous bumps. I have seen at least four species of *Nerita* in reef tanks, and there are undoubtedly more than that. They tend to be dark; browns and blacks are the predominant colors, but there are several species that are white with rich brown markings.

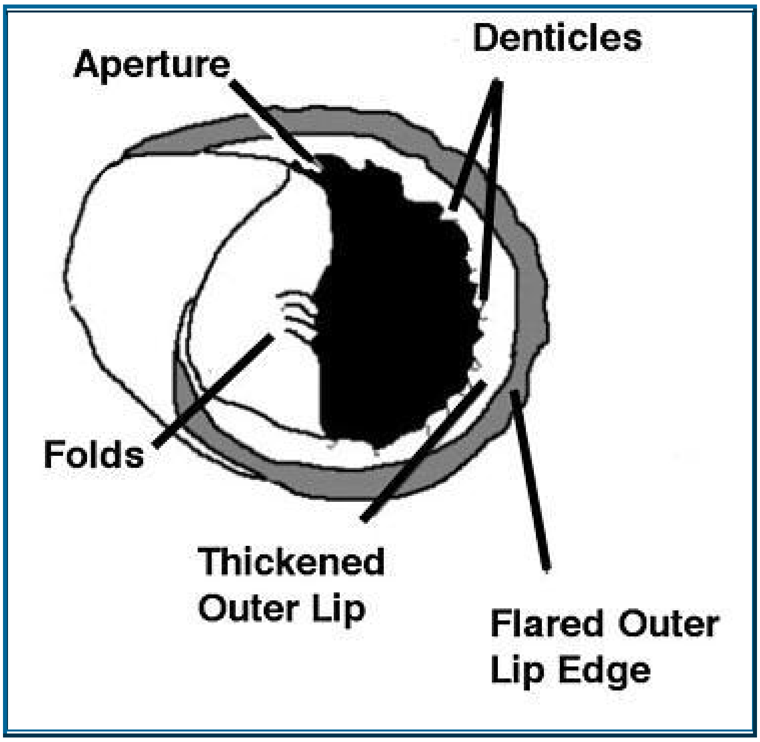


Figure 3. Diagram of a Nerite shell showing the aperture and some of the diagnostic characters used in identification.

Some of the ones collected for sale in reef tanks are really intertidal marsh animals and have no business in a reef tank. I am not the only one who thinks so, by the way. The snails agree with me, and vote with their feet, moving out of the tank and into the wilds of the adjacent rooms. These animals will live in the tank, but seem to have a physiological need to move above the water line. At least in many cases, unlike some of the limpets, they also move back down to the water.

offered for sale are intertidal or subtidal as the shells are quite similar.

There are several other *Nerita* species that don't have the vertical wanderlust, and these make good grazers on the glass and elsewhere. These animals seldom harm other species in our systems, although they may occasionally bulldoze some unattached structures around. *Nerita* females lay egg masses frequently, but the larvae seldom pass through the larval stage and juveniles are seldom seen in our systems. The largest nerites in our systems are about 2 cm (0.75 in) across, and the smallest are adult at 1-2 mm (1/12th to 1/25th of an inch) across. Well-fed Nerites lay eggs almost continuously on the aquarium rocks and walls. The white eggs are enclosed in a protective covering and develop from egg to larvae within it for about a week or so. The egg capsule then opens and the larvae are released into the tank's water. This feeding larval stage is prolonged and it is unlikely any larvae will survive to settle and metamorphose in a reef aquarium.

Conclusion:

With the exception of the *Nerita*, the snails that I have written about in this column are not often seen in reef aquaria. *Haliotis asinina* are fine grazers, as well as attractive animals, and even though they are aquacultured and have been marketed to hobbyists, their availability is spotty. Relatively few species of limpets suitable for the hobby are available and not many vendors have them. The shield and fleshy limpets are neat additions to reef tanks, but I know of no vendor that specifically and consistently offers them for sale. Next month, I will conclude this short series on the shelled snails that eat algae with some information on some animals that are readily available: ceriths, strombids, cowries, columbellids, and some bubble shells.

If you have any questions about this article, please visit my author **forum** on Reef Central.

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Reef Aquarium Salinity: Homemade Calibration Standards

One of the most important issues facing marine aquarists is providing a suitable environment for their aquaria's inhabitants. Among the important properties for a marine environment's suitability is the water's salinity level. Water that is either too saline or not saline enough can be stressful or lethal to many organisms. Deciding what salinity level to maintain in a reef aquarium can be a complicated task, especially if the organisms come from different environments. This article includes a brief discussion of how to select an appropriate salinity target, but selection is not the main purpose of this article.

Monitoring the salinity level is an important issue itself, wholly apart from deciding what salinity level to target in an aquarium. Fortunately, a number of different methods for monitoring salinity are available to aquarists, including specific gravity (via hydrometers), refractive index (via refractometers), and conductivity (via electronic meters). In order to get the most out of any one of these methods, however, aquarists must have confidence that it provides reliable information. Each method can provide perfectly adequate information for aquarists, assuming that the device used is properly manufactured, calibrated, and used. Alternatively, each device can provide misleading information if any of these factors is not optimal.

Calibration of an analytical instrument is the best way of ensuring that the information that it is providing is accurate. While there are many ways to calibrate instruments for salinity determination, the simplest is to test the instrument using a solution with a known salinity. In that case, it is best if that standard has a salinity close to the samples likely to be tested, which in this case is close to natural seawater. If the instrument reads the appropriate value, it will be suitable for use by the aquarist. If not, then the device, or the aquarist's interpretation of the results, might need to be altered ("calibrated") to give the correct reading.

Aquarists can purchase commercial calibration standards that will permit calibration of each of these methods to a high degree of accuracy. These standards, however, can be expensive, and in many cases, complicated to use. One reason that commercial standards can be difficult to use, for example, is that they usually come standardized to units of measurement related to the technique, rather than to the unit of measurement the aquarist needs: conductivity for conductivity meters, refractive index for refractometers, and density or specific gravity for hydrometers.

Unfortunately, the reef aquarium hobby has seen a rapid expansion of devices for measuring salinity that report in units that they are not actually measuring. For example, how can a hobbyist use a refractive index standard (such as a solution with a known refractive index of 1.3850) when the refractometer reads in units of specific gravity?

This article describes a series of homemade calibration standards that can be made from sodium chloride (table salt) and purified fresh water. These solutions can be used to calibrate refractometers, hydrometers, and conductivity probes. While not likely to be as accurate as commercial standards (depending on the ability to accurately measure weights and volumes), they will be adequate for most reef aquarium purposes. At the very least, they can be used to prevent a seriously defective device from causing an aquarist to provide a grossly inappropriate salinity level in a reef aquarium.

Table 1 shows the relevant properties of seawater as a function of salinity. In order to make a standard for each method, it is necessary to determine what concentration of sodium chloride solution matches the appropriate property of seawater.[1-3] In this article, I will use solutions with the same properties as seawater with a salinity of 35 PSU (often written as S=35). PSU is an acronym for practical salinity units, which is essentially a modern replacement for ppt, since salinity is no longer defined as directly relating to solids in the water, but rather by its conductivity. How each standard is made and used is detailed for each of the different methods in subsequent sections.

Table 1. Specific gravity, conductivity, and refractive index as a function of salinity of seawater. The darker blue rows represent the range usually encountered in the open ocean.

Salinity (PSU)	Specific Gravity at 25° C[3]	Conductivity (mS/cm; 25° C)[3]	Refractive Index (20° C)[1]
0	1.0000	0	1.33300
30	1.0226	46.2	1.33851
31	1.0233	47.6	1.33869
32	1.0241	49.0	1.33886
33	1.0249	50.4	1.33904
34	1.0256	51.7	1.33922
35	1.0264	53.0	1.33940
36	1.0271	54.4	1.33958
37	1.0279	55.7	1.33994
38	1.0286	57.1	1.34012
39	1.0294	58.4	1.34031

General Salinity Discussion

As far as I know, there is little evidence that keeping a coral reef aquarium at anything other than a natural salinity level is preferable. It appears to be common practice to keep marine fish, and in many cases reef aquaria, at somewhat lower than natural salinity levels. This practice stems, at least in part, from the belief that fish are less stressed at reduced salinity. Substantial misunderstandings also arise among aquarists as to **how specific gravity really relates to salinity**, especially considering temperature effects.

Ron Shimek has discussed salinity on natural reefs in a **previous article**. His recommendation, and mine as well, is to maintain salinity at a natural level. If the organisms in the aquarium are from brackish environments with lower salinity, or from the Red Sea with higher salinity, selecting something other than S=35 may make good sense. **Otherwise, I suggest targeting a salinity of S=35 (specific gravity = 1.0264; conductivity = 53 mS/cm).**

Making Standards with Table Salt

Making salinity standards with ordinary table salt requires the ability to make salt solutions of known concentration. The standards given in this article are all best made using accurate weight measurements, both of the salt and the water. Most aquarists, however, do not have access to high quality balances, so volume-based measurements will be provided. Typically, they will not be as accurate as weight-based measurements, but will be adequate for most aquarium purposes.

A recent article in an **online culinary magazine** suggested that measuring spoons used by cooks are actually a fairly accurate way to measure volumes. In particular, they showed that of the many teaspoons tested, all were within 1% of the standard volume:

"Measuring spoons don't usually get a lot of consideration: bought once and done. But have you ever wondered if your set of spoons is accurate? Would an expensive set do a better job? To find out, the test kitchen purchased 10 different sets of measuring spoons, made from both plastic and stainless steel and ranging in price from $1.99 to $14.99.

We were prepared for large differences in degree of accuracy but found none. All of the spoons weighed in within a few hundredths of a gram of the official standard-not enough to compromise even the most exacting recipe."

Consequently, aquarists can use measuring spoons for measurement of salt volumes. If they have an accurate balance, all the better. In that case, they should just use the mass specified, rather than the volume.

To measure with a measuring spoon or cup that is measured to the top, first overfill it, then use the back of a knife to carefully level the volume. I did this with a variety of different measuring spoons and cups using Morton's Iodized Salt, and got the following results:

- 5 teaspoons = 31.13 g, or 6.2 grams per teaspoon (equivalent to 1.26 g/dry mL)
- 5 tablespoons = 91.04 g, or 18.2 g/tablespoon (equivalent to 1.23 g/dry mL)
- ¼ cup = 73.07 g (equivalent to 1.24 g/dry mL)
- ½ cup = 156.52 g (equivalent to 1.32 g/dry mL)
- 1 cup = 296.62 g (equivalent to 1.25 g/dry mL)

Figure 1. Salt creep is one way that salinity can change over time. This extreme case was captured in a photo by Bob Bottini (aquababy) owner of Tanks alot!

In this case, only the ½ cup deviated from a fairly standard value. Overall, the **Salt Institute** suggests that 1 teaspoon of a variety of different salt brands weighs about 6 grams (1.22 g/dry mL):

"The density of granulated evaporated salt varies depending on crystal size, structure, gradation, and degree of compaction. The reported range of densities is 1,200-1,300 g/L." We will use 1.217 g/mL, which gives 6 grams per teaspoon."

Measuring the water's volume is best done with an accurate measuring container of appropriate dimensions. In the absence of such a container, however, I have measured a container whose volume may be standardized across the United States, and which may therefore allow reasonably accurate volume measurement. In particular, a plastic 2-L Diet Coke bottle filled to the absolute top contained 2104.4 grams (mL) of water. In a pinch, these containers may serve well as volume standards (at least until the company changes bottle styles).

Refractometer Standard

It is widely believed that only pure water is required to calibrate refractometers. That fact is true of many refractometers, and is certainly appropriate for routine calibration, but it assumes that they were manufactured correctly and have not been damaged since manufacturing. As refractometers used by aquarists become less and less expensive (with some now selling for less than $30), there is every reason to believe that at some point they will no longer be accurate enough.

The only way to be sure that a given refractometer gives useful information is to check its accuracy in a solution similar to aquarium water. I believe that all refractometers should be checked in this fashion when first purchased, and again any time there is a reason to be concerned. For example, an aquarist might be concerned if an aquarium that had been running for years at a salinity of 35 ppt suddenly reads 39 ppt.

In order to provide a standard for refractometers, a solution whose refractive index is similar to normal seawater is required. Seawater with S= 35 has a refractive index of 1.3394.[1] Likewise, the refractive index of different sodium chloride solutions can be found in the scientific literature. My CRC Handbook of Chemistry and Physics (57th Edition, Page D-252)[4] has such a table. That table has entries for 3.6 and 3.7 weight percent solutions of sodium chloride that span the value for normal seawater. Interpolating between these data points suggests that **a solution of 3.65 weight percent sodium chloride has the same refractive index as S=35 seawater, and can be used as an appropriate standard** (Table 2).

Table 2. Refractive Index as a function of the concentration of a sodium chloride solution.[1,4] The darker blue row represents the standard.

Sodium Chloride Concentration (weight %)	Refractive Index	Salinity (PSU)
3.3	1.3388	31.65
3.4	1.3390	32.8
3.5	1.3391	33.3
3.6	1.3393	34.4
3.65	1.3394	35.0
3.7	1.3395	35.6
3.8	1.3397	36.7

This 3.65 weight percent sodium chloride solution can be made by dissolving 3.65 grams of sodium chloride in 96.35 grams (mL) of purified fresh water. That amount roughly corresponds to ¼ cup (73.1 g) of Morton's Iodized Salt dissolved into 2 liters (2000 g) of water (giving very slightly more than 2 L of total volume).

For a rougher measurement in the absence of an accurate water volume or weight measurement:

1. Measure ¼ cup of Morton's Iodized Salt (about 73.1 g)
2. Add 1 teaspoon of salt (making about 79.3 g total salt)
3. Measure the full volume of a plastic 2-L Coke or Diet Coke bottle filled with purified fresh water (about 2104.4 g)
4. Dissolve the total salt (79.3 g) in the total water volume (2104 g) to make an approximately 3.65 weight percent solution of NaCl. The volume of this solution will be slightly larger than the Coke bottle, so dissolve it in another container.

How to Use a Refractive Index Standard

One simple way to use this refractive index standard is to measure it with a refractometer, and just remember what setting the standard came to. That setting represents S=35 seawater, with all of the properties shown in Table 1. Hopefully, the reading of the refractometer at that point will be similar to the properties in Table 1 (specific gravity = 1.026 - 1.027, or S=35, depending on the units). Simply using it as the target salinity for the aquarium is a fine way to go.

Alternatively, one can actually calibrate the refractometer using the standard by adjusting it until it reads the appropriate setting indicated in Table 1. Exactly how to adjust it depends on the refractometer, but often it is as simple as turning a screw.

Specific Gravity Standard

Most aquarists recognize that inexpensive hydrometers are often prone to error. In some cases, inaccuracy is due to poor manufacturing, and in other cases it is due to poor usage by aquarists. In a **previous article** I tested several hydrometers and found variable results, from good to marginal. Beyond the inherent accuracy of the measurement is the confusing problem of how specific gravity relates to the temperature of the measurement, an issue which I detailed in that same **article**.

The best way to be sure that a given hydrometer is giving accurate information is to check its accuracy in a solution with a density (specific gravity) similar to the aquarium water. In order to provide a standard for hydrometers, a solution of a similar specific gravity to normal seawater is required. Seawater with S= 35 has a specific gravity of about 1.0264 (Tables 1 and 3).

Table 3. Density and specific gravity as a function of salinity of seawater.[3] The darker blue rows represent the range usually encountered in the open ocean.

Salinity (PSU)	Density (25° C)	Specific Gravity (25° C)
0	997.05	1.0000
29	1018.8	1.0218
30	1019.6	1.0226
31	1020.3	1.0233
32	1021.1	1.0241
33	1021.8	1.0249
34	1022.6	1.0256
35	1023.3	1.0264
36	1024.1	1.0271
37	1024.9	1.0279
38	1025.6	1.0286
39	1026.4	1.0294

In order to match this specific gravity to a standard solution made from sodium chloride, look up the density of different sodium chloride solutions in the scientific literature. My CRC Handbook of Chemistry and Physics (57th Edition, only for 20°C (68°F). Specific gravity at 20°C is then easily calculated by dividing the density of the solutions by the density of water at the same temperature. This table (4) can then be compared to seawater at 20°C (Table 5). The primary purpose of showing specific gravity at 25°C (77°F; Tables 1 and 3) and 20°C (Table 4) is to show that specific gravity does not change much with temperature (1.0264 vs. 1.0266). Nevertheless, it is only the 20°C data that will be used to devise a standard.

The table in the CRC Handbook has entries for 3.7 and 3.8 weight percent solutions of sodium chloride that span the specific gravity value for normal seawater. Interpolating between these data points suggests that **a solution of 3.714 weight percent sodium chloride has the same specific gravity (and density) as S=35 seawater, and can be used as an appropriate specific gravity standard** (Table 5). For most purposes, 3.7 weight percent is accurate enough.

Table 4. Density and specific gravity as a function of salinity of seawater at 20° C.[4] The darkened blue rows represent the range usually encountered in the open ocean.

Salinity (PSU)	Density (25° C)	Specific Gravity (25° C)
0	988.2	1.0000
29	1020.2	1.0220
30	1021.0	1.0228
31	1021.7	1.0236
32	1022.5	1.0243
33	1023.2	1.0251
34	1024.0	1.0258
35	1024.8	1.02660
36	1025.5	1.0274
37	1026.3	1.0281
38	1027.1	1.0289
39	1027.8	1.0297

Table 5. Specific gravity as a function of the concentration of sodium chloride in water. The values in the medium blue boxes are interpolated and the darker blue row represents the standard.[3,4]

Sodium Chloride Concentration (weight %)	Specific Gravity at 20° C	Salinity
3.4	1.0243	32.0
3.5	1.0250	32.9
3.6	1.0257	33.8
3.7	1.0265	34.8
3.71	1.02657	34.9
3.714	1.02660	35.0
3.72	1.02664	35.1

3.73	1.02671	35.1
3.74	1.02678	35.2
3.8	1.0272	35.8

To produce a 3.714 weight percent sodium chloride solution, dissolve 1 teaspoon (6.20 grams) of Morton's Iodized Salt in 161 mL (161 g) of fresh water (making a total volume of about 163 mL after dissolution of the salt). This solution can be scaled up as desired.

For a rougher measurement in the absence of an accurate water volume measurement:

1. Measure ¼ cup of Morton's Iodized Salt (about 73.1 g)
2. Add 1½ teaspoon of salt (making about 82.4 g total salt)
3. Measure the full volume of a plastic 2-L Coke or Diet Coke bottle filled with purified fresh water (about 2104.4 g)
4. Add an additional 2 tablespoons of purified fresh water (about 30 g)
5. Dissolve the total salt (82.4 g) in the total water volume (2134.4 g) to make an approximately 3.7 weight percent solution of NaCl. The volume of this solution is larger than the Coke bottle, so dissolve it in another container.

How to Use a Specific Gravity Standard

Depending on the type of hydrometer, one would use this solution differently.

For standard floating hydrometers (Figure 2), which are **not self-correcting for temperature variations**, it is important to use the standard at the same temperature at which the aquarium water will be tested (within say, ± 0.5 ^{o}C or ± 1 ^{o}F). Preferably, that will also be the temperature at which the hydrometer is intended to be used (often marked on it), but that is not an absolute requirement. The aquarist can then mark on the hydrometer the level to which it rises (that is, the water line), and use that as an indication of the specific gravity of S=35 seawater, which has all of the properties listed in Table 1(specific gravity = 1.0264, etc). If the hydrometer reads higher or lower than 1.0264, then the aquarist can just imagine the scale on the hydrometer to be shifted up or down, and shift all other readings taken with it (at the same temperature) by the same amount.

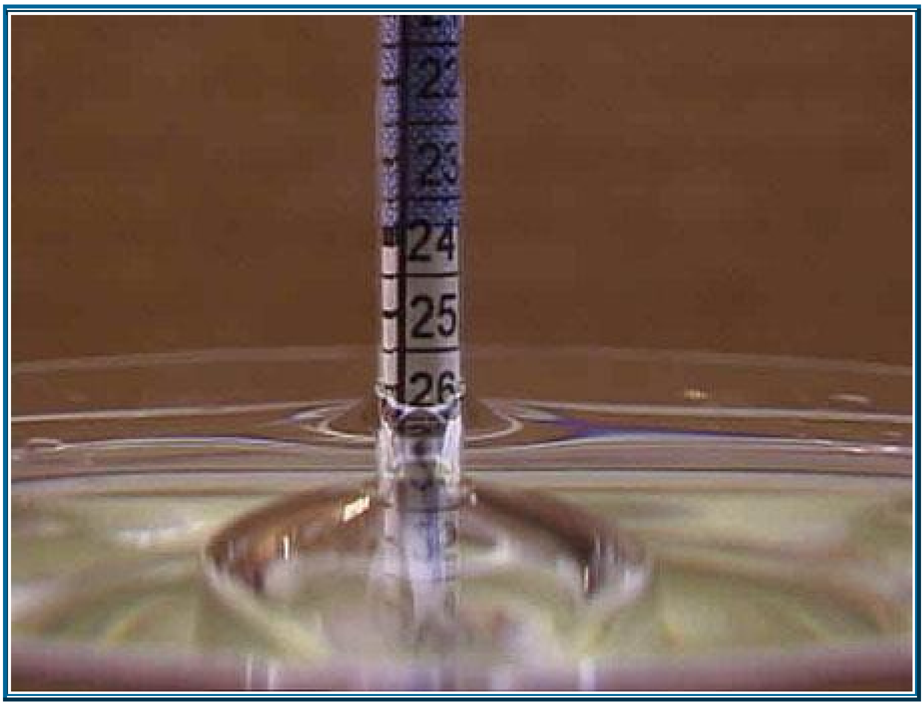

Figure 2. The Tropic Marin floating hydrometer.

For example, if the standard comes out at 1.0230 (and it is really 1.0264), then just add 1.0264 - 1.0230 = 0.0034 to each measured value).

For swing arm hydrometers (Figure 3), which are largely **self-correcting for temperature** variations, add the standard to the swing arm hydrometer at roughly the same temperature at which the aquarium water will be tested (say, ± 5°C or ± 10°F). Once the reading stabilizes, the aquarist can mark the reading (or just remember it) and use that as an indication of the specific gravity of S=35 seawater, which has all of the properties listed in Table 1 (specific gravity = 1.0264, etc). If the hydrometer reads higher or lower than 1.0264, then the aquarist can just imagine the scale on the hydrometer to be shifted up or down, and shift all other readings taken with it by the same amount, just as for a standard floating hydrometer.

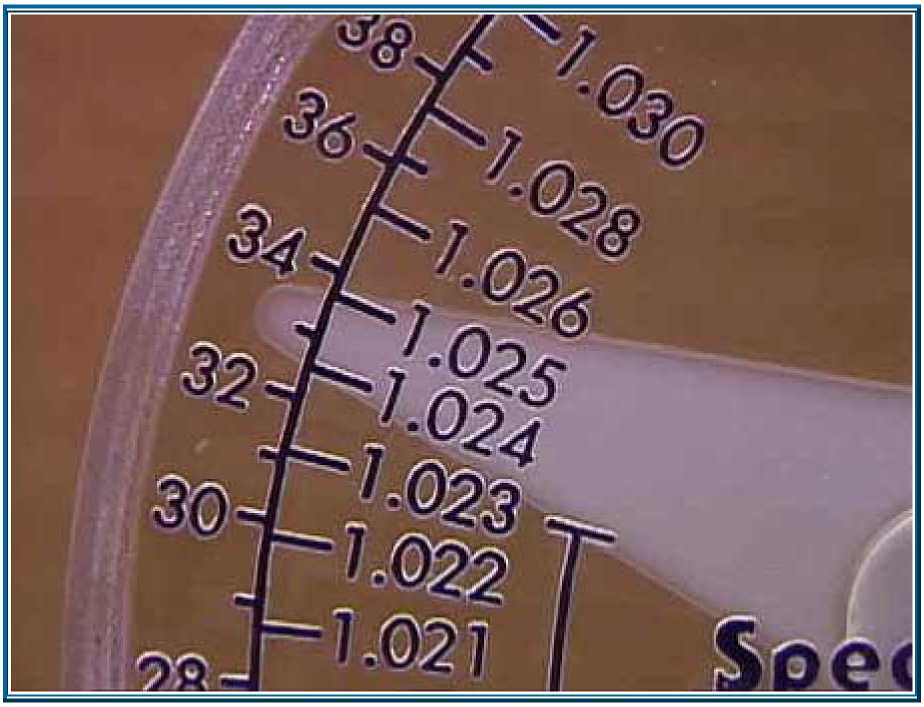

Figure 3. The SeaTest swing arm hydrometer.

Just to be especially clear: this solution need not be used at exactly 20ºC (68ºF). It will be just about as accurate at 25ºC (77ºF) since specific gravity does not change much with temperature, and these salt solutions would be expected to change density with temperature in about the same fashion as seawater. The most important factor is that the temperature of the standard, when measured, be the same as the aquarium water when it is measured..

How to Use a Standard Hydrometer

Here are a few additional tips for using a hydrometer:

1. Make sure that the hydrometer is completely clean (no salt deposits) and that the part of the hydrometer above the water line is dry. Tossing it in so it sinks deeply and then bobs to the surface will leave water on the exposed part that will weigh down the hydrometer and give a falsely low specific gravity reading. Salt deposits above the water line will have the same effect. If any deposits won't easily dissolve, try washing it in dilute acid (such as vinegar or diluted muriatic acid).
2. Make sure that there are no air bubbles attached to the hydrometer. These will help buoy the hydrometer and yield a falsely high specific gravity reading.
3. Make sure that the hydrometer is the same temperature as the water (and preferably the air).
4. Read the hydrometer at the plane of the water's surface, not along the meniscus (Figure 2; the meniscus is the lip of water that either rises up along the shaft of the hydrometer, or curves down into the water, depending on the hydrophobicity of the hydrometer).
5. Rinse with purified freshwater after use to reduce deposits.
6. Do not leave the hydrometer floating around in the tank between uses. If left in the aquarium, deposits may form that will be difficult to remove.

How to Use a Swing Arm Hydrometer

In addition to those described above, here are some special tips for swing arm hydrometers:

7. Make sure that the hydrometer is completely level. A slight tilt to either side will change the reading.
8. Some swing arm hydrometers recommend "seasoning" the needle by filling it with water for 24 hours prior to use. This presumably permits the water absorbed into the plastic to reach equilibrium. In the case of the hydrometer that I tested in a previous article, the hydrometer became slightly less accurate after "seasoning."

Conductivity Standard

Conductivity can readily be used to measure the salinity of seawater. In a **previous article** I detailed how this measurement works and why it is suitable for reef aquaria. In short, the more ions there are in solution, the more easily the solution will conduct electricity. In fact, conductivity is so easily measured and standardized that it forms the basis of the modern definition of salinity, PSU (Practical Salinity Units). S=35 seawater is defined as seawater with the same conductivity as a solution made from 3.24356 weight percent potassium chloride (KCl), and that conductivity is exactly 53 mS/cm (mS/cm is one of the units used for conductivity, it is milliSiemens per centimeter). Higher and lower conductivities give higher and lower salinities, respectively, using a complicated equation that will not be discussed here.

There are two ways to formulate a conductivity standard that matches S=35 seawater. The first is looking to the scientific literature to see what sodium chloride solutions provide a conductivity of 53 mS/cm. A second is to match a sodium chloride solution to the conductivity of 3.24 weight percent potassium chloride in water. This article does both.

First, the scientific literature. Fortunately, **many measurements of conductivity of such solutions** have been made over the years. Without going into detail about how they were measured, the data from these papers indicate that a 53 mS/cm conductivity solution is provided by a 33.64 g/L (0.576 M) sodium chloride solution. That solution corresponds to 3.29 weight percent sodium chloride.[2]

Alternatively, one can measure conductivity of salt solutions. I made a solution of 3.24 weight percent KCl in deionized water and measured its conductivity. The reading on the uncalibrated meter was 52.5 mS/cm (it would have been 53 mS/cm with a perfectly calibrated meter).

I then made a solution of deionized water and Morton's Iodized Salt, adding salt until I matched the conductivity of the prior solution. It required EXACTLY 3.29 weight percent sodium chloride to match this conductivity. Believe it or not, I didn't even recognize the close agreement between these two methods during the test, as I hadn't worked through the math until long after taking the original measurements.

So not only is there good evidence that a 3.29 weight percent sodium chloride solution is appropriate, but additional evidence demonstrates that Morton's Iodized Salt from a grocery store is a suitable material for this purpose.

To make a 3.29 weight percent sodium chloride solution, dissolve 1 teaspoon (6.20 grams) of Morton's Iodized Salt in 182 mL (182 g) of fresh water (making a total volume of about 184 mL after dissolution of the salt). This solution can be scaled up as desired.

For a rougher measurement in the absence of an accurate water volume measurement:

1. Measure ¼ cup of Morton's Iodized Salt (about 73.1 g)
2. Measure the full volume of a plastic 2-L Coke or Diet Coke bottle filled with purified fresh water (about 2104.4 g)
4. Add 3 tablespoons of purified fresh water (about 45 g)
5. Dissolve the total salt (73.1 g) in the total water volume (2149.4 g) to make an approximately 3.29 weight percent solution of NaCl. The volume of this solution is larger than the Coke bottle, so dissolve it in another container.

How to Use a Conductivity Standard

How to best use a conductivity standard depends a bit on the meter involved. If the meter can be calibrated, then my suggestion is to get the solution to about 25°C (exactly that temperature if the meter doesn't automatically compensate for temperature, but that would be unusual) and then adjust the meter until it reads 53 mS/cm or S=35 (depending on the output).

Many meters, however, do not allow such calibration. In that case, measure the conductivity or salinity of the standard, and then set up a correction ratio that is applied manually. For example, if the standard reads 56 mS/cm, then multiply all readings on that meter by 53/56 (0.946) to get a corrected reading. The same correction could apply to salinity. For example, if it reads S=38 (or 38 ppt), then multiply every reading by 35/38 = 0.921.

Alternatively, the simplest way is to use the value that is found from the standard as the target for the aquarium, and not worry about calibrations or corrections.

Summary

This article provides a way for reef aquarists to make and use salinity standards for the most common ways of measuring salinity: refractometers, hydrometers, and conductivity meters. Hopefully, these will help aquarists avoid problems that might arise from poorly calibrated devices, or at least ease their concerns about whether or not their devices are working properly.

Happy Reefing!

If you have any questions about this article, please visit my author **forum** on Reef Central.

References:

1. The data on the refractive index of seawater as a function of salinity were obtained from:

Practical Handbook of Marine Science, Third Edition Michael J. Kennish; Editor (2000) 896 pp, Publisher: Lewis Publishers, Inc.

2. The data on the conductivity of sodium chloride solutions were obtained from:

Conductances of concentrated aqueous sodium and potassium chloride solutions at 25°C Chambers, J. F.; Stokes, Jean M.; Stokes, R. H. Univ. W. Australia, Nedlands, J. Phys. Chem. (1956), 60 985-6.

3. Data for the physical properties of seawater (other than refractive index) came from a calculator on the Ocean Teacher web site of the Intergovernmental

Oceanographic Commission (IOC):

http://ioc.unesco.org/oceanteacher/~Calculator.htm

4. **CRC Handbook of Chemistry and Physics. 57th ed**. Weast, Robert C.; Editor. (1976), 2400 pp. Publisher: (Chem. Rubber Co., Cleveland, Ohio).

Notes FROM THE TRENCHES with Agu Lukk

A Simple DIY Kalk Dripper

Perhaps you've read in a book or magazine, or maybe somewhere online, that you need to "drip kalk" as your makeup water. Everyone makes it sound so easy that you really don't want to ask how to actually do it. You're wondering if it's expensive, if it is difficult, and if it is dangerous to your tank? The answers, in order, are: no, no, and no. After reading this web page, you'll be confidently dripping kalk like a pro. The benefits of using kalkwasser will not be discussed here as it has been thoroughly covered in many articles by Randy Holmes-Farley (**Link 1**, **2**,).

You'll need only a few tools: a drill, drill bits, scissors, and a hacksaw blade (optional).

You'll also need some supplies, so make your shopping list. The first stop in this shopping spree will be the grocery store, where you'll be buying a container, some pickling lime, and measuring spoons. First, the container needs to be food grade, preferably made of plastic as glass tends to be too heavy, and second, it should have a screw-on plastic cap. Various sizes of bottled water or sports drink containers work well, although a one or two liter glass bottle will be fine. The size of the container selected should depend on the size of the tank and the amount of evaporative loss. Larger tanks will need larger size containers as they evaporate more water and consequently need more top-off water replaced. In my case, all of my tanks are under 10 gallons, so the size containers pictured here worked fine. Or, alternatively, if the aquarium has a lot of evaporation, consider making two containers; one can be settling while the other is operating and dripping kalk. I've found this to be a viable alternative to carrying large containers of kalk and attempting to secure a heavy container above the tank or sump. Next, purchase some pickling lime (not pickling spice), if the store has any in stock. If they don't have any, that's not a problem; a suitable substitute can be found at our next stop. For a more thorough discussion of the various pickling limes available, see **this article** by Randy Holmes-Farley. Finally, buy your own set of plastic measuring spoons dedicated for this purpose, you don't want to be sharing food preparation measuring spoons and you'll always want the equipment to be availabe. Keep in mind the spoon has to fit in the mouth of the container you've selected. I've found elongated spoons are much more useful than the typical round measuring spoons.

The next stop is the local fish store. If pickling lime wasn't available at the grocery store, buy some kalkwasser powder here. You'll pay more, but at least they have it in stock, and this project is generally so cheap that you can afford to splurge. Additionally, a length of rigid tubing will be needed; I use 3/16" thin-walled tubing. You'll also need flexible tubing. Before buying it, however, be sure it fits over the rigid tube easily but snugly. I've found most fish stores stock flexible vinyl tubing that is just a little bit too small and difficult to work with, so I stop by the local hardware store and buy the tubing there. The final item to pick up from the local fish store is a small package of plastic airline valves.

So now you have your supplies...

From top left: airline valve kit, Ball's pickling lime, the container, flexible airline tubing, rigid airline tubing, and measuring spoons.

...and you're looking at this conglomeration of stuff and wondering what's next...

Grab the drill! The container's cap needs to have two holes drilled in it (see below). In my case, I used a 7/32" drill bit. A bit of advice... before drilling the top, find a scrap piece of plastic and drill a test hole to confirm the flex tubing fits snugly. Once the correct bit size is determined, drill two holes in the cap, making sure they aren't too close to the edge, since the cap needs to be able to screw back onto the bottle.

Note the position of the holes in the cap.

The manner in which to assemble the dripper depends on the container used and where it's located relative to the tank. For example, the length of the tubing depends on how far the container will be located from the point you've chosen in the aquarium to dose the kalkwasser. In all cases, however, the tube inside the bottle should end about 3/4" above the bottom. There will be some residue that settles out and you don't want to add that to your system as it may contain some **undesirable metal residues**. I also use rigid tubing on the outside because flex tends to be difficult to work with, and I've been known to accidentally drip a whole container of kalk outside the tank when using only flex tubing.

The flexible airline tubing is run through the hole in the cap and connected to the rigid tubing. A short length of flexible tubing connects the two pieces of rigid tubing, and a small section of flex tubing is inserted into the end where the valve is placed.

By now you're probably wondering about three things: 1) do you have to suck on the drip tube to start the siphon, 2) what does kalk taste like, and 3) what's with the second hole in the cap? Quick answers are: no, I've never tasted it, and it's the siphon starter. Cut another piece of flex tubing and insert it about 1/4" into the second hole. Blowing into the second tube pressurizes the container and forces water into the siphon tube. This assumes, of course, that the airline valve is open. The DIY kalk dripper is now ready for use. Congratulations on a successful project!

The assembled kalk dripper. Note the siphon tube installed in the picture on the right.

Now that the kalk dripper is assembled, next comes the not-so-daunting task of using it.

It's important when planning, and prior to building, the kalk dripper, to find a location in the aquarium where it can drip into turbulent water. Placing the drip into turbulent water assures better dispersion throughout the tank. Also make sure it's safely supported; a kalk container falling and spilling its entire contents can be a disastrous event! Plan the size of the container with the assumption that something will fail and the entire contents may drain quickly into the tank. Some potential pitfalls could include such things as the airline valve falling off (unlikely), the container springing a leak (unlikely), or forgetting to turn down the drip rate after starting the siphon (likely).

The general rule of thumb for mixing kalkwasser is one teaspoon of kalk powder per gallon of water. Fill about 1/3 of the container with RO/DI water and add the kalk. Swirl it around until it's in suspension, then add the rest of the water and cap the container. Be careful with this part, as kalk can be an irritant if it gets onto your skin. I usually mix the kalk in the evening and set the container in place without starting a drip. The next morning it takes just a few seconds to start the siphon and set the drip rate. The proper drip rate depends upon your setup and the water volume of your system. For my small tanks, about one drip per second is slow enough not to cause sudden pH fluctuations and still get the kalk in the tank; obviously, larger tanks can handle faster additions of kalk.

There is some minor maintenance involved in dripping kalk. First, you'll discover a sludge accumulating in the bottom of the container; simply pour it out periodically. Eventually, the airline valve and tubing will start to clog with calcium deposits. You'll realize this when the drip rate becomes hard to regulate or stops completely. Either dripping plain RO/DI water through it every couple of weeks or removing the valve and soaking it in vinegar will easily solve this problem.

Two kalk drippers, utilizing different sized containers, in operation on the author's tanks.

If you have any questions about this article, please visit my author **forum** on Reef Central.

Reefkeeping's Top Ten

Top Ten Thread Titles That You Never Want To See Again On Reef Central...

10) How do I get rid of *Aiptasia*?
keckles of Tulsa

9) DSB- Yes or No?
drtherc of Northern California

8) Slightly used Reef Central thong (XXXL) for sale.
reefyguy of Indianapolis

7) Help me identify this new invertebrate [No picture attached].
shearwater of Boxford, MA

6) Anything that has the word "NEMO" in it!
Tasiamay of Phoenix, Arizona

5) Anything written by WaterKeeper!!!
WaterKeeper of SW Ohio

4) TEST.
mktexas of unknown whereabouts

3) How many tangs do I need to solve the algae problem in my 30 gallon reef tank?
ozadars of Turkey / Izmirof

2) Does anyone know where I can get some Southdown?
Thunnus of Austin, Texas

1) The story of the gonad-eating butt fish!
TurboBrett of Austin, TX 78745, BlAcK_PeRcUlA of So. Cal and fishinchick of So. Cal.

Reefkeeping's next Top Ten for July: **Top Ten Stupidest Questions Overheard In Your Local Fish Store...** Our thanks go out to GaVitroN for suggesting the next topic!

Honorable mention goes out to the following members for submitting ten Top Ten reasons: reefyguy, jeffltodd, Whiterat, Reef Bass, K9Decoy and skylsdale. Thanks, folks!

Think you're funny? Send us an entry (via the Submit button or the forum link below) for the **Top Ten Stupidest Questions Overheard In Your Local Fish Store...**

If you have questions, would like to suggest a future Top Ten topic or place an entry, visit our online **forum** or hit the button below: