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MARICULTURE OF AQUARIUM FISHES

N. Forteath, Inspection Head Wharf, Tasmania, Australia

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Introduction

Marine fishes and invertebrates have been kept in aquaria for decades. However, attempts to maintain marine species in a captive environment have been dependent on trial and error for the most part but it has been mainly through the attention and care of aquarists that our knowledge about many marine species has been obtained. This is particularly true of the charismatic syngnathids, which includes at least 40 species of sea horses.

During the past 30 years, technological advances in corrosion resistant materials together with advances in aquaculture systems have brought about a rapid increase in demand for large public marine aquarium displays, oceanariums and hobby aquaria suitable for colorful and exotic ornamental species. These developments have led to the establishment of important export industries for live fishes, invertebrates and so-called ‘living rocks’. Attempts to reduce dependence on wild harvesting through the development of marine fish and invertebrate hatcheries met with limited success.

The availability of equipment, which greatly assists in meeting the water quality requirements for popular marine organisms, has turned the attention of aquarists towards maintaining increasingly complex living marine ecosystems and more exotic species. A fundamental requirement for the success of such endeavors is the need to understand species biology and interspecific relationships within the tank community. Modern marine aquarists must draw increasingly on scientific knowledge and this is illustrated below with reference to sea horse and coral reef aquaria, respectively.

History

The first scientific and public aquarium was built in the London Zoological Gardens in 1853. This facility was closed within a few years and another attempt was not undertaken until 1924. By the 1930s several public aquaria were built in other European capitals but by the end of World War II only that of Berlin remained. During the 1970s the scene was set for a new generation of public aquaria, several specializing in marine displays, and others becoming more popularly known as oceanariums due to the presence of marine mammals, displays of large marine fish and interactive educational activities.

Themes have added to the public interest. For example, Monterey Bay Aquarium exhibits a spectacular kelp forest, a theme repeated by several world class aquaria and Osaka Aquarium sets out to recreate the diverse environments found around the Pacific Ocean. Some of these aquaria have found that exhibits of species native to their location alone are not successful in attracting visitor numbers. The New Jersey Aquarium, for example, has been forced to build new facilities and tanks housing over 1000 brightly colored marine tropical fish with other ventures having to rely on the lure of sharks and touch pools.

The history of public aquaria has evolved from stand alone tank exhibits to massive 2–3 million liter tanks through which pass viewing tunnels. Once, visitors were content to be mere observers of the fishes and invertebrates but by the end of the millennium the emphasis changed to ensuring the public became actual participants in the aquarium experience. The modern day visitors seek as near an interactive experience as possible and hope to be transformed into the marine environment and witness for themselves the marine underwater world.

The concept of modern marine aquarium-keeping in the home has its origins in the United Kingdom and Germany. The United States is now the world’s most developed market in terms of households maintaining aquaria, especially those holding exotic marine species: there are about 2.5 million marine hobby aquariums in the USA. In Holland and Germany, the emphasis has been on reef culture, a hobby which is becoming more widespread. The manufacture of products designed specifically for the ornamental fish trade first began in 1954 and scientific and technical advances during the 1960s brought aquarium keeping a very long way from the goldfish and goldfish bowl. The development of suitable materials for marine aquaria has been hampered by the corrosive nature and the toxicity of materials when immersed in sea water. One of the first authoritative texts on materials and methods for marine aquaria was written by Spotte in 1970, followed by Hawkins in 1981.

The volume of marine ornamental fish involved in the international trade is difficult to calculate accurately since records are poor. Current estimates are between 100 and 200 tonnes per annum which probably corresponds to more than 20 million individual specimens. The trade is highly dependent on harvesting from the wild. In Sri Lanka, Indonesia, the Philippines, Fiji and Cook Islands, the export of tropical reef species is now one of the most important export industries employing significant numbers of village people.

Members of the family Pomacentridae, in particular clown fishes, *Amphiprion* spp., and blue–green chromis, *Chromis viridis*, are central to the industry and cleaner wrasse, *Labroides dimidiatus*, flame angels, *Centropyge loriculus*, red hawks, *Neocirrhites armatus*, tangs, *Acanthus* spp., and seahorses, *Hippocampus* spp. are important. The fire shrimp, *Lysmata debelius*, is a major species with respect to invertebrates.

Historically, culture of marine ornamentals has not been in competition with the wild harvest industry. However, recent advances in aquaculture technology will undoubtedly enable more marine ornamentals to be farmed. One European hatchery already has an annual production of *Amphiprion* spp. which is 15 times that exported from Sri Lanka, whereas in Australia seahorse farming is gaining momentum. In both Europe and USA, commercial production of fire shrimp, *L. debelius*, is being attempted. To date the greatest impediment to culture lies in the fact that many popular marine ornamentals produce tiny, free-floating eggs and the newly hatched larvae either do not accept traditional prey used for rearing such as rotifers and brine shrimp, or the prey has proved nutritionally inadequate.

During the 1980s, the Dutch and German aquarists pioneered the development of miniature reef aquaria. Their success among other things, depended on efficient means of purifying the water. The Dutch developed a 'wet and dry' or trickle filter. These filters acted as both mechanical and biological systems. More compact and efficient trickle filter systems have been developed with the advent of Dupla bioballs during the 1990s. These aquaria are filled with so-called 'living rock' which is initially removed from coral reefs.

Coral culture *per se* has recently been established in the Philippines, Solomon Islands, Palau, Guam, and the United States and is aimed at reducing the need to remove living coral from natural reefs.

The upsurge in popularity in marine ornamentals over the past 30 years for both public and hobby aquaria has raised serious conservation concerns. There are calls for sustainable management of coral reefs worldwide and even bans on harvesting of all organisms including 'living rock'.

The sea horses in particular have received attention from aquarists and conservationists. Sea horses are one of the most popular of all marine species and are probably responsible for converting more aquarists to marine aquarium-keeping than any other fish. Unlike most other marine ornamentals sea horses have been bred in captivity for many years.

In 1996, the international conservation group TRAFFIC (the monitoring arm of the World Wide Trust for Nature) claimed sea horses were under threat from overfishing for use in traditional medicines, aquaria, and as curios. According to TRAFFIC at least 22 countries export sea horses, the largest known exporters being India, the Philippines, Thailand and Vietnam. Importers for aquaria include Australia, Canada, Germany, Japan, The Netherlands, United Kingdom, and the United States. The species commonly in demand are shown in **Table 1**.

The greatest problem for both sides in the debate over the trade in wild-caught marine ornamental fishes in general is a historical lack of scientific data on the biology of these animals both in their natural and captive environments. It is true to say that most of the information about marine ornamentals is derived from intelligence gathering by aquarists and scientific rigor has been applied in the case of only a few species. One such species is the pot-bellied sea horse, *Hippocampus abdominalis*, which has been studied both in the wild and captive environment for several years. Data on this species serve as useful comparative tools for knowledge about other ornamental fishes.

The Pot-bellied Sea Horse and Other Aquarium Species

Species Suitability for Aquaria

Table 2 sets out major parameters affecting life support in marine aquaria. Factors about a species that it would be advantageous to know prior to

Table 1 Sea horse species commonly kept in aquaria

Aquarium common name	*Species name*	*Geographic reference*	*Size (cm)*	*Color*
Dwarf sea horse	*Hippocampus zosterae*	Florida coast	5	Green, gold, black, white
Northern giant	*H. erectus*	New Jersey coast	20	Mottled, yellow, red, black, white
Spotted sea horse	*H. reidi*	Florida coast	18	Mottled, white, black
Short-snouted	*H. hippocampus*	Mediterranean	15	Red/black
Mediterranean	*H. ramulosus*	Mediterranean	15	Yellow/green
Golden or Hawaiian	*H. kuda*	Western Pacific	30	Golden
Pot-bellied sea horse	*H. abdominalis*	Southern Australian coast	30	Mottled, gold, white, black

selection for the aquarium are:

- water temperature range,
- water quality requirements,
- behavior and habitat (territorial, aggressive, cannibalistic, pelagic, benthic),
- diet,
- breeding biology,
- size and age,
- ability to withstand stress,
- health (resistance and susceptibility).

Table 2 Parameters affecting life support in marine aquaria

Parameter	*Factor*
Physical	
Temperature	
Salinity	
Particular matter	Composition
	Size
	Concentration
Light	Artificial/natural
	Photoperiod
	Spectrum
	Intensity
Water motion	Surge
	Laminar
	Turbulence
Chemical	
pH and alkalinity	
Gases	Total gas pressure
	Dissolved oxygen
	Un-ionized ammonia
	Hydrogen sulfide
	Carbon dioxide
Nutrients	Nitrogen compounds
	Phosphorus compounds
	Trace metals
Organic compounds	Biodegradable
	Nonbiodegradable
Toxic compounds	Heavy metals
	Biocides
Biological	
Bacteria	
Virus	
Fungi	
Others	

Water Temperature Range

The pot-bellied seahorse *H. abdominalis* has a broad distribution along the coastal shores of Australia, being found from Fremantle in Western Australia eastwards as far as Central New South Wales, all around Tasmania and also much of New Zealand. Within its range water temperatures may reach 28°C for several months and fall to 9°C for a few weeks. Acclimation trials in the laboratory and in home aquaria have shown that this species will live at water temperatures as high as 30°C and as low as 8°C. Unlike many marine ornamental fishes, *H. abdominalis* is eurythermal.

Many marine aquaria are kept between 24 and 26°C which is considered satisfactory for a number of marine ornamentals, however some species require higher temperatures, for example some butterfly fishes (Chaetodontidae) survive best at 29°C. Many tropical coral reef species are stenothermous and are difficult to maintain in temperate climates without accurate thermal control. The more eurythermous a species, the easier it will be to acclimate to a range of water temperature fluctuations.

Water Quality Requirements

Salinity The salinity of sea water may alter due to freshwater run-off or evaporation. Some marine species are less tolerant than others to salinity changes, and it is important to determine whether or not a species will survive even relatively minor changes. *H. abdominalis* is euryhaline, growing and breeding at salinities between 15–37 parts per thousand (‰). It is a coastal dwelling species being recorded at depths of 1–15 m and may be present in a range of habitats from estuaries, open rocky substrates and artificial harbors. Often, pot-bellied sea horses can be found attached to nets and cages used to farm other fish species. The somewhat euryecious behavior of this sea horse has probably resulted in its broad tolerance of salinities.

Many marine aquaria depend on artificial sea water which is purchased as a salt mixture and added to dechlorinated fresh water. Natural sea water is a complex chemical mixture of salts and trace elements. It has been shown that some artificial seawater mixtures are unsuitable for marine plants and even particular life stages of some fishes. Particular attention must be paid to trace elements in coral reef aquaria when using either natural or artificial salt water. Coral reef aquaria are also more sensitive to salinity changes than general fish aquaria. **Table 3** gives a useful saltwater recipe.

Other Water Quality Guidelines

Various tables have been provided setting out water quality guidelines for mariculture. **Table 4** is useful for well-stocked marine fish and coral reef aquaria but is possibly too rigid for lightly stocked fish tanks.

The toxicity of several parameters given in **Table 3** may be reduced by ensuring the water is always close to saturation with respect to dissolved oxygen concentration (DOC). Studies on *H. abdominalis* have indicated that this species becomes stressed when DOC falls below 85% saturation. Furthermore, the species is tolerant of much higher un-ionized ammonia (NH_3-N) levels when the water is close to DOC saturation. A combination of low dissolved oxygen ($<80\%$) and NH_3N greater than $0.02\,mg\,l^{-1}$ may result in high mortalities.

Ammonia is the major end product of protein metabolism in sea horses and most aquatic animals. It is toxic in the un-ionized form (NH_3). Ammonia concentration expressed as the NH_3 compound is converted into a nitrogen basis by multiplying by 0.822. The concentration of un-ionized ammonia depends on total ammonia, pH, temperature, and salinity. The concentration of un-ionized ammonia is equal to:

$$\text{Un-ionized ammonia } (mg\,l^{-1} \text{ as } NH_3\text{-N}) = (a)(\text{TAN})$$

where a = mole fraction of un-ionized ammonia and TAN = total ammonia nitrogen ($mg\,l^{-1}$ as N).

Table 5 gives the mole fraction for given temperatures and pH in sea water.

The concentration of un-ionized ammonia is about 40% less in sea water than fresh water, but its toxicity is increased by the generally higher pH in the former. **Figure 1(A)** shows the operation of a simple subgravel filter which removes ammonia and nitrite by nitrification and **Figure 1(B)** shows the configuration of a power filter using both nitrification and absorption to remove ammonia. Both methods have been used to maintain water quality in marine ornamental aquaria.

Unfortunately, information on toxicity levels of ammonia for marine ornamentals is poorly documented but **Table 4** is probably a useful guide given the data on cultured species.

The pot-bellied sea horse is intolerant to even low levels of hydrogen sulfide (H_2S) (**Table 4**). This gas is difficult to measure at low levels thus care is required to avoid anoxic areas in aquaria. H_2S is almost certainly toxic to other marine ornamentals also, particularly reef dwellers.

Chlorine, copper and zinc have all proved toxic to *H. abdominalis* at levels exceeding those shown in **Table 4**. Chorine and copper are often used in aquaria: the former to sterilize equipment and the

Table 3 The Wiedermann–Kramer saltwater formula

In 100 liters of distilled water:	
Sodium chloride (NaCl)	2765 g
Magnesium sulfate crystals ($MgSO_4 \cdot 7H_2O$)	706 g
Magnesium chloride crystals ($MgCl_2 \cdot 6H_2O$)	558 g
Calcium chloride crystals[a] ($CaCl_2 \cdot 6H_2O$)	154 g
Potassium chloride[a] (KCl)	69.7 g
Sodium bicarbonate ($NaHCO_3$)	25 g
Sodium bromide (NaBr)	10 g
Sodium bicarbonate ($NaCO_3$)	3.5 g
Boric acid (H_3BO_3)	2.6 g
Strontium chloride ($SrCl_2$)	1.5 g
Potassium iodate (KIO_3)	0.01 g

[a]The potassium chloride should be dissolved separately with some of the 100 liters of distilled water as should the calcium chloride. Add these after the other substances have been dissolved.

Table 4 Water quality levels for the aquarium

Parameter	*Level*
Dissolved oxygen	90–100% saturation ($>6\,mg\,l^{-1}$)
Ammonia	$<0.02\,mg\,l^{-1}$ NH_3-N
Nitrite	$<0.1\,mg\,l^{-1}$ NO_2-N
Hydrogen sulfide	$<0.001\,mg\,l^{-1}$ as H_2S
Chlorine residual	$<0.001\,mg\,l^{-1}$
pH	7.8–8.2
Copper	$<0.003\,mg\,l^{-1}$
Zinc	$<0.0025\,mg\,l^{-1}$

Table 5 Mole fraction of un-ionized ammonia in sea water[a]

Temp (°C)	*pH*				
	7.8	7.9	8.0	8.1	8.2
20	0.0136	0.0171	0.0215	0.0269	0.0336
25	0.0195	0.0244	0.0305	0.0381	0.0475
30	0.0274	0.0343	0.0428	0.0532	0.0661

[a]Modified from Huguenin and Colt (1989).

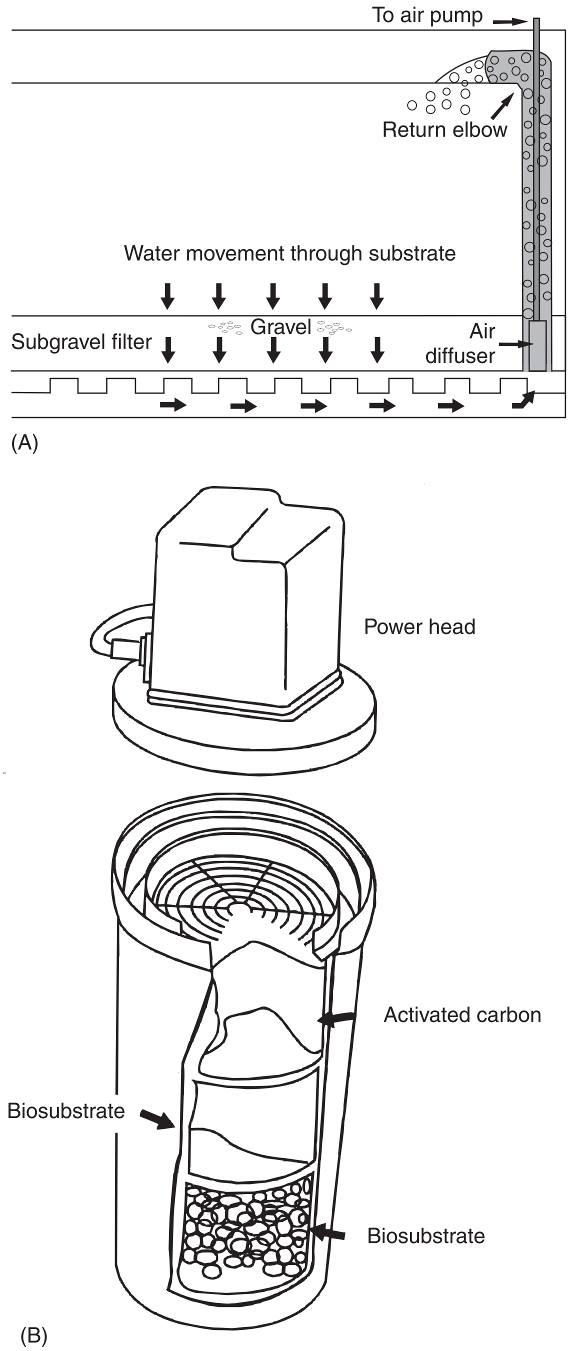

Figure 1 (A) Undergravel filtration within an aquarium tank. (B) Canister filter with power head and filter media chambers.

latter in treatment of various diseases. Furthermore, chlorine may be present in tap water when mixed with artificial seawater mixtures. Great care is required in the use of these chemicals. Available aquarium test kits are seldom sensitive enough to detect chronic chlorine concentrations. Often 1–5 $mg\,l^{-1}$ sodium thiosulfate or sodium sulfite are used to remove chlorine but for some marine species these too may prove toxic. Bioassays for chlorine toxicity using marine ornamentals have not been carried out.

Copper toxicity can be significantly reduced with the addition of 1–10 $mg\,l^{-1}$ of EDTA. EDTA is also a good chelating agent for zinc.

Behavior and Habitat

It is widely believed that sea horses spend their time anchored by their prehensile tails to suitable objects. This is not necessarily true. *H. abdominalis* is an active species feeding both in the water column and over the substratum. However, at night the fish 'roosts' often in association with other specimens. Furthermore, this species is remarkably gregarious and stocking levels as high as 10 fish, 6 cm in length per liter, have been regularly maintained in hatchery trials.

Although sea horses may tolerate the presence of several of their own species, their slow feeding behavior puts them at a competitive disadvantage in a mixed species aquarium, where faster feeders will ingest the sea horses' food.

Predation is a serious problem in marine aquaria. Sea horses are known to be prey for other fishes both in the wild and in aquaria. Members of the antennariids, particularly the sargassum fish, *Histrio histrio*, are known to feed on sea horses as are groupers (Serranidae) and trigger Fishes (Balistinae), flatheads (Platycephalidae) and cod (Moridae).

Territorial species are common among the coral-dwelling fishes and such behavior makes them difficult to keep in mixed-species aquaria. The blue damsel, *Pomacentrus coelestris*, shoals in its natural habitat but becomes pugnacious in the confines of the aquarium.

Several marine ornamentals seek protection or are cryptic. The majority of clown or anemone fish (*Amphiprion*) retreat into sea anemones if threatened, in particular, the anemones *Stoichaetis* spp., *Radianthus* spp., and *Tealia* spp., whereas some wrasse dive beneath sand when frightened. Cryptic coloration is seen in the sea horses and color changes have often been reported.

The cleaner wrasse, *Labroides dimidiatus*, lives in shoals over reefs but is successfully maintained singly in the aquarium, where even the most aggressive fish species welcome its attention. Other wrasses mimic the coloration and shape of *L. dimidiatus* simply to lure potential prey towards them.

Behavior and habitat of many marine ornamentals has been gleaned from observation only, but failure to understand these factors make fish-keeping difficult.

Diet

The dietary requirements are poorly known for marine ornamentals and many artificial feeds may do little more than prevent starvation without live or frozen feed supplements. Furthermore, a given species may require different foods at various life stages. Several stenophagic species are known in the aquarium mainly consisting of algal and live coral feeders, for example the melon butterfish *Chaetodon trifasciatus*. The diet of others may not even be known in spite of such fish being sold for the aquarium. The regal angelfish, *Pygoplites diacanthus*, seldom lives for long in the aquarium and dies from starvation.

Sea horses are easy to feed but require either live or frozen crustacea or small fish. The pot-bellied seahorse has been reared through all growth stages using diets of enriched brine shrimp, *Artemia salina*, live or frozen amphipods, small krill species, and fish fry. The ready acceptance and good growth rates recorded in hatchery-produced pot-bellied sea horses using 48-h-old enriched brine shrimp have resulted in significant numbers of sea horses being raised in at least one commercial farm. Apart from hatcheries for clown fishes and pot-bellied sea horses, the intensive culture of marine ornamentals has proved difficult due to a lack of suitable prey species for fry.

Breeding Behavior

Breeding behavior can be induced in several ornamental fishes with appropriate stimuli and environments. The easier species are sequential hermaphrodites such as serranids. The pomacentrids of the genus *Amphiprion* are a further good example. However, sea horses have been extensively studied.

The sea horses are unique in that the male receives, fertilizes and broods the eggs in an abdominal pouch following a ritualized dance. Much has been made of monogamy but as further studies are undertaken scientific support for such breeding behavior is being questioned. *H. abdominalis* is polygamous both in the wild and captivity.

The pot-bellied sea horse in captivity, at least, shows breeding behavior as early as four months of age and males may give birth to a single offspring; by one year of age males may give birth to as many as 80 fry and at two years of age 500 fry. Precocity in other marine ornamentals is not recorded but may exist.

Size and Age

The size and age of aquarium fish have been seldom studied scientifically but has been observed. Groupers (Serranidae) and triggerfishes (Balistinae) quickly outgrow aquaria, and some angelfishes and emperors may show dramatic color changes with age, becoming more or less pleasing to aquarists.

Longevity likewise is unknown for most marine ornamentals but the pygmy sea horse *H. zosterae* lives for no more than two years, whereas *H. abdominalis* may live for up to nine years.

Stress

Stress probably plays a pivotal role in the health of marine ornamentals but scientific studies have not been undertaken. The aquarist would do well to remember that stress suppresses aspects of the immune response of fishes and that studies on cultured species demonstrate that capture, water changes, crowding, transport, temperature changes, and poor water quality induce stress responses. Furthermore, stress can be cumulative and some species may be more responsive than others. Farmed species tend to show a higher stress threshold than wild ones. The potential advantage of purchasing hatchery-reared ornamentals (if available) are obvious, since survival in farmed stock should be greater than in wild fish held in aquaria.

Health Management

Good health management results from an understanding of the biological needs of a species. Treatment with chemicals is a short-term remedy only and the use of antibiotics may exacerbate problems through bacterial resistance.

A considerable number of pathogens have been recorded in marine aquarium fishes and include viruses, bacteria, protozoa, and metazoa. Most diseases have been shown not to be peculiar to a given species but epizootic. For example, several of the disease organisms recorded in sea horses, in particular *Vibrio* spp., protozoa and microsporidea, are known to infect other fish species also.

In coral reef aquaria, nonpathogenic diseases due to poor water quality may be common and in-depth knowledge pertaining to the husbandry of such systems is essential for their well-being.

Coral Reef Aquaria

The Challenge

The coral reef is one of the best-adapted ecosystems to be found in the world. Such reefs are biologically derived and the organisms which contribute substantially to their construction are hermatypic corals although ahermatypic species are present. Coral reefs support communities with a species diversity that far exceeds those of neighboring habitats and the symbiotic relationship between zooxanthellae and the scleractinian corals are central to the reef's well-being. Zooxanthellae are also present in many octocorallians, zoanthids, sea anemones, hydrozoans and even giant clams. As zooxanthellae require light for photosynthesis, the reef is dependent on clear water.

Coral reefs are further restricted by their requirement for warm water at 20–28°C, and the great diversity of life demands a plentiful supply of oxygen. The challenge for the aquarist lies in the need to match the physical parameters of the water in the aquarium as closely as possible with sea water of the reef itself.

Physical Considerations

Temperature The recommended water temperature for coral reef aquaria is a stable 24°C. The greater the temperature fluctuations the less the diversity of life the aquarium will support. At temperatures less than 18°C the reef will die and above 30°C increasing mortalities among zooxanthellae will occur leading to the death of hermatypic corals.

Light Water bathing coral reefs has a blue appearance which has been called the color of ocean deserts. Most of the primary production is the result of photosynthesis by benthic autotrophs (zooxanthellae) rather than drifting plankton. Photosynthetic pigments of zooxanthellae absorb maximally within the light wavelength bands that penetrate furthest into sea (400–750 μm) and therefore clear oceanic water is essential.

In the aquarium, both fluorescent and metal halides are available which will supply light at the correct wavelength. Actimic-03 fluorescents combined with white fluorescents are suitable. Typically three tubes, two actinic and one white, will be needed for a 200 liter tank. Metal halide lamps cannot be placed close to the tank because of heat and such lamps produce UV light which will destroy some organisms. A glass sheet placed over the aquarium will prevent UV penetration. One 175 W lamp is recommended per 60 cm of aquarium length.

Water movement Coral reefs are subjected to various types of water movements, namely surges, laminar currents, and turbulence. These water motions play an essential role by bringing oxygen to the corals and plants, removing detritus and, in the case of ahermatypic corals, transporting their food.

In the aquarium these necessary water movements must be present. Power head filters are available which produce acceptable surges and currents.

Biological Considerations

Nutrients Coral reefs are limited energy and nutrient traps: rather than being lost to deep water sediments, some organic compounds and nutrients are retained and recycled. However, water movements rid the reef of dangerous excess nutrients which might promote major macrophyte growth.

The coral reef aquarium soon becomes a nutritional soup if both organic compounds and nutrients are not recycled or removed. Although skilled and knowledgeable aquarists are able to use the biological components of the reef itself to produce an autotrophic system, most employ protein skimmers, mechanical filters and biological filters to prevent poisoning of the system. **Figure 2** represents nutrient cycling over a coral reef and **Figure 1(B)** shows a suitable filter for reef aquaria. Removal of nitrate can be achieved through the use of specialized filters which grow denitrifying bacteria.

Living rock Living rock is dead compacted coral which has been colonized by various invertebrates. In addition, there will be algae and bacteria. Different sources of living rock will provide different populations of organisms. Over time the organisms which survived the transfer from reef to aquarium become established and the aquarium is ready for corals. By the time the corals are placed in the aquarium all filter systems must be operating

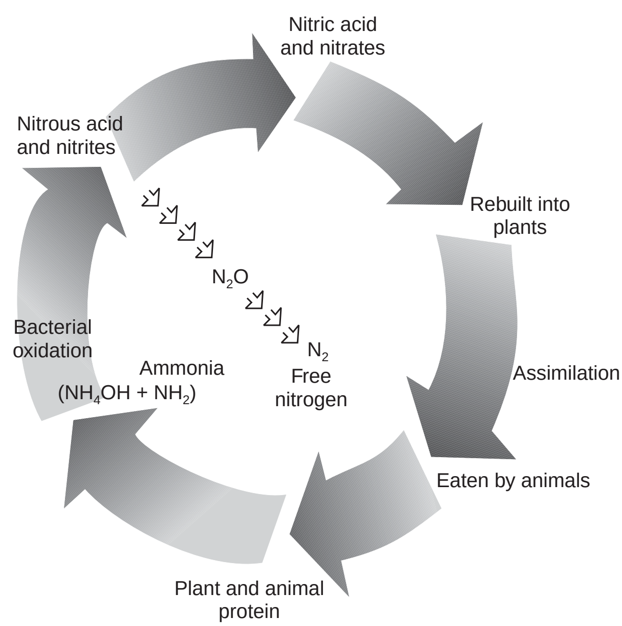

Figure 2 Nutrient cycling over a coral reef.

Table 6 Some additional faunal components for coral reef aquaria

Niche	*Common name*	*Scientific name*
Detritus feeder	Anemone shrimp	*Periclimenea brevicarpalis*
	Shrimp	*P. pedersoni*
	Fiddler crab	*Uca* spp.
Algal feeder	Tiger cowrie	*Cypraea tigris*
	Money cowrie	*C. moneta*
	Starfish	*Patiria* spp.
Plankton feeders	Mandarin fish	*Synchiropus splendidus*
	Psychedelic fish	*S. picturatus*
	Midas blenny	*Escenius midas*

efficiently. Ahermatypic corals should be introduced first and placed in the darker regions of the tank since they feed on plankton. Once hermatypic corals are introduced appropriate blue light for at least 12 hours each day must be available, and strict water quality maintained (**Table 4**). Nitrate must not rise above $15\,mg\,l^{-1}$ and pH fall below 8.

Additional faunal components The living rock will introduce various invertebrates. Additional species must be selected carefully and on a scientific rather than an esthetic basis. The introduction of detritus and algal feeders will probably be essential and coral eaters must be avoided. Fish species require high protein diets which will necessitate further reductions of ammonia, nitrite, and nitrate from the aquarium. The species given in **Table 6** might be considered but there are many others. Selection will depend on the inhabitants.

See also

Corals and Human Disturbance. Coral Reefs. Coral Reef and other Tropical Fisheries. Mariculture Diseases and Health. Mariculture Overview.

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MARICULTURE OF MEDITERRANEAN SPECIES

G. Barnabé, Université de Montpellier II, France
F. Doumenge, Musée Océanographique de Monaco, Monaco

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Basic Requirements

Obtaining Stock for Ongrowing

The starting point of any farming operation is the acquisition of stock for rearing; these may be spat for mollusks or alevins, fry or juveniles for fish.

From the wild For the Mediterranean mussel (*Mytilus galloprovincialis*), spat is always collected from the wild, from rocky shores or shallow harbors where they are abundant. Conditions are less favorable for oyster culture; the native (flat) oyster (*Ostrea edulis*) is captured only in the Adriatic and the other remnants of natural stocks are unable to support intensive culture. Spat from Japanese (cupped) oysters (*Crassostrea gigas*) has to be imported from the Atlantic coast. Clam culture utilizes both spat from Mediterranean species (*Tapes decussatus*) and a species originating in Japan (*Tapes philippinarum*) which has spread very rapidly, especially in the Adriatic.

Juvenile marine fish such as eels (*Anguilla anguilla*), mullets (*Mugil* sp.), gilthead sea bream (*Sparus aurata*) and sea bass (*Dicentrarchus labrax*) are traditionally captured in spring in the mouths of rivers or in traps or other places in protected lagoons in Italy; these form the basis of the valliculture of the northern Adriatic, a type of extensive fish culture. In practice, elvers and yellow eels are supplied mainly from fisheries in other Mediterranean lagoons, especially in France.