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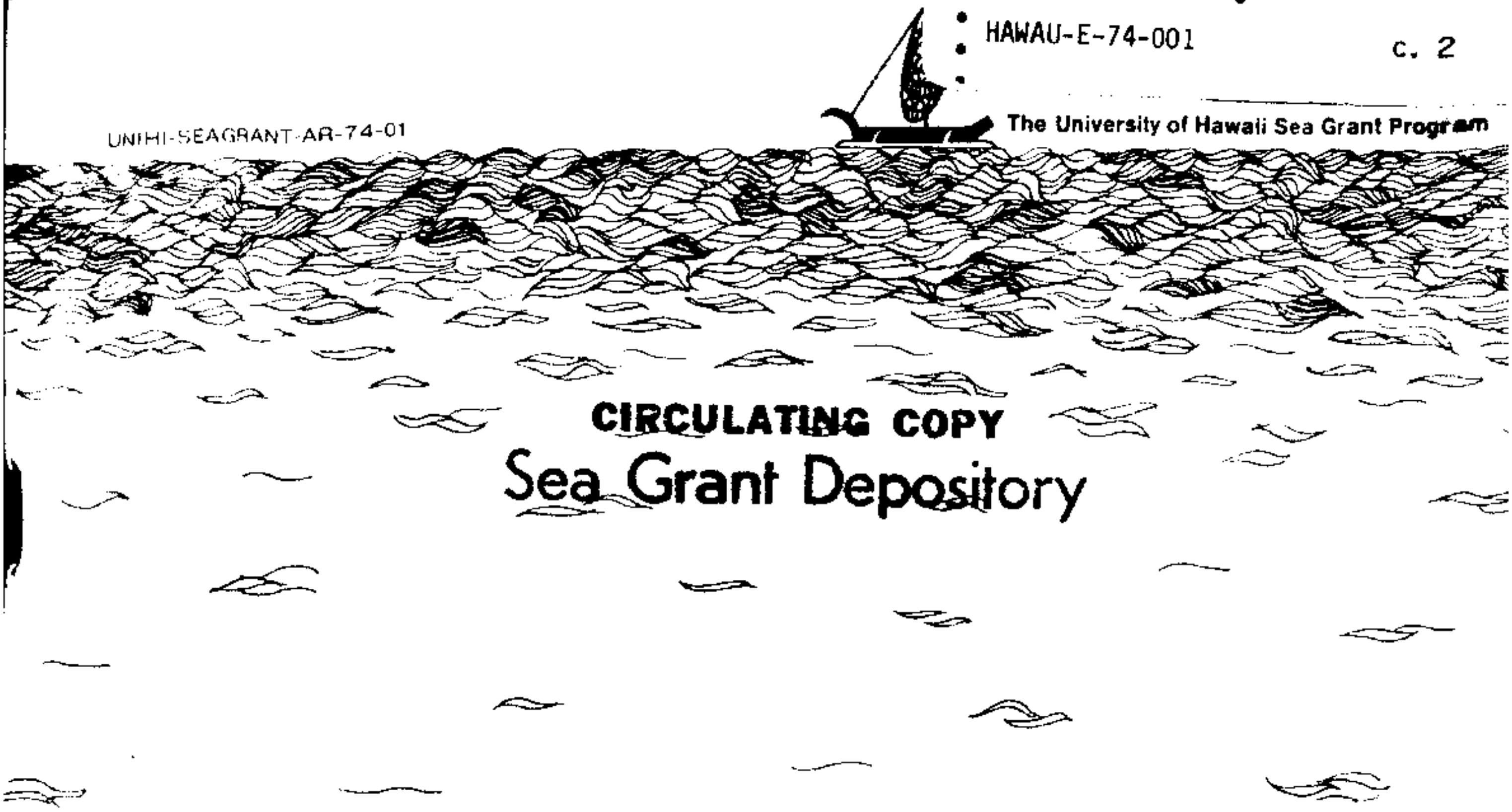

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Marine and Freshwater Aquarium Systems for Tropical Animals

E.H. Chave and P.S. Lobel

April 1974

MARINE AND FRESHWATER AQUARIUM SYSTEMS FOR TROPICAL ANIMALS

by

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PREFACE

This syllabus attempts to synthesize published and unpublished material on tropical aquatic organisms and their maintenance. Few courses have been taught on the subject and as far as we know there are no publications, to date, that cover the subject area completely enough to be used as text material. The contents of this syllabus constitute a baseline for the beginner to help him maintain aquatic organisms in captivity. The syllabus is not designed for the advanced aquarist, since he may already have good ideas on how to keep his animals. It is incomplete in some areas because we have attempted not to be redundant in areas where our references thoroughly explain the problems encountered by aquarists. We also encourage our readers to help us make the syllabus more complete by contributing their suggestions. These will be acknowledged when the syllabus is revised.

Our collaborators played a major part in helping to write three sections of this syllabus: Miss J.B. Culp, COLLECTING AND TRANSPORTING TROPICAL FISHES; Dr. K.E. Chave, WATER CHEMISTRY; Dr. G.S. Losey, SYMBIOTIC BEHAVIOR.

Miss M.L. Berman illustrated the syllabus. We also acknowledge the help of Dr. L.G. Katz of Cleveland, Ohio, and Dr. R.M. Nakamura of Animal Sciences, University of Hawaii, for their help on fish diseases. We wish to thank Dr. A.S. Reed of the Zoology Department, University of Hawaii for Appendix 3 and Dr. L. Taylor of the same department for reviewing the manuscript. We also wish to thank Dr. J. Bauer, and Mr. L. Davis, of the Cleveland Aquarium Society, and Mr. G. Klay of Marathon, Florida for their help and advice in the past. Especial thanks to Mrs. S. Morris for her editorial suggestions. We also acknowledge the aid of various members of our 1972 and 1973 Aquarium Management classes.

Through the National Oceanic and Atmospheric Administration's Sea Grant program we were able to purchase the equipment and supplies to initiate the course and publish this syllabus.

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I. INTRODUCTION*

Tropical aquatic animals come from regions between 30°N and 30°S latitudes (approximately) where surface water temperatures exceed 18°C (64°F) during the winter. Most of this fauna consist of small animals which can be maintained in aquaria. They live in freshwater lakes and streams, brackish water estuaries, island and continental coral reefs, or shallow marine habitats lacking reefs (*e.g.*, sea grass beds, pen shell beds, rocky areas).

Most tropical marine and freshwater animals originated in the Tethys Sea, an immense shallow-water area that covered much of Europe, Asia, and part of North America from 100 to 50 million years ago. Fifty million years ago temperatures changed and our continents began to drift into their present positions. The animals that survived are the ancestors of those species we know today. These ancestral groups have had 50 million years to develop into discrete species and migrate to other areas. Many marine species remained in the Western Pacific which today contains the richest faunal assemblage in the world.

A. Requirements of Species

A species is defined as the smallest persistent unit in life. In other words, a species in its natural habitat produces organisms similar in structure and heredity to itself. Usually if two species interbreed, they produce no young or their progeny are sterile. About 100,000 and 300,000 tropical aquatic invertebrate and vertebrate species are described in the literature (excluding plankton) and many of which could be maintained in small aquaria. Approximately 650 species of fish have been described from Hawaii and of these about 300 may be kept in aquaria.

Each species has some different requirements making it unique. It would take many years to describe all that has been written about them. Consequently, in this syllabus only the requirements of the more common groups are discussed.

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*For further information consult references 16, 22, 27, 29, and 40.

1. Space

All animals require a certain amount of space around themselves which many of them defend. This area may be large or small depending on an individual's reproductive condition, the amount of food and shelter in an area, and the number and kind of other individuals in the same area.

2. Shelter

Specific organisms often prefer different types of shelter, some in coral heads, some in caves, some under overhangs. Some are associated with particular organisms or substrates, *e.g.*, anemone fishes and anemones, some wrasses with sand.

3. Water Quality, Water Movement, Light Intensity, and Temperature

Some organisms can tolerate wide fluctuations in these conditions; some cannot.

4. Food

Marine and freshwater organisms may be herbivores (plant eaters), carnivores (animal eaters), or omnivores (a little of both). Some require specific foods; *e.g.*, the harlequin or clown shrimp feeds only on sea stars.

B. Requirements of Communities

Communities in the broad sense are groups of organisms that occur together and have many similar requirements. The members of a community are generally compatible with each other. Ideally, one should collect fishes and invertebrates from a single area and keep them together, thus creating a more stable aquarium than one containing animals from different areas. For example, in Hawaii we have coral communities which flourish in areas of low surge, fairly clear flowing water with hard substrates and open ocean salinities. Members of the community are the corals themselves, algae, and most of our colorful reef fishes and invertebrates which often use the corals as shelter. Our stream communities need soft, fresh rapidly flowing water with rocks and boulders for shelter; they consist of algae, fishes, and invertebrates adapted to clinging to rocks or wedging themselves between rocks.

The animal species in a community must also be different from one another, in order to survive as species. If two species acted exactly in the same way, one of them would eventually gain the advantage over the other because it would be more efficiently able to utilize resources such as food and shelter. Members of communities may not spend their lives in one area but may join other communities. For example, the eggs and young of many marine fishes and invertebrates join the planktonic community for a period of time.

As with all species and communities, marine communities are governed by the physical factors associated with depth, temperature, wave action, water quality, and light. In Hawaii and other tropical islands there are five general areas from which most of our saltwater fishes are obtained. (See Figure 1.)

1. Tidepool zones formed by wave action cutting into the rock.
2. Shallow lagoon or back-reef areas that usually have poor water circulation and are sandy with a few corals and rubble.
3. Fringing or barrier reef tops with rich algal growth. The water is well mixed, rough, and shallow.
4. Fringing or barrier reef slopes with rich coral growth and well-circulated water.
5. Sand and dead reef areas at the bottom of the reef slope. These areas are too deep for coral growth, but have open-ocean water conditions.

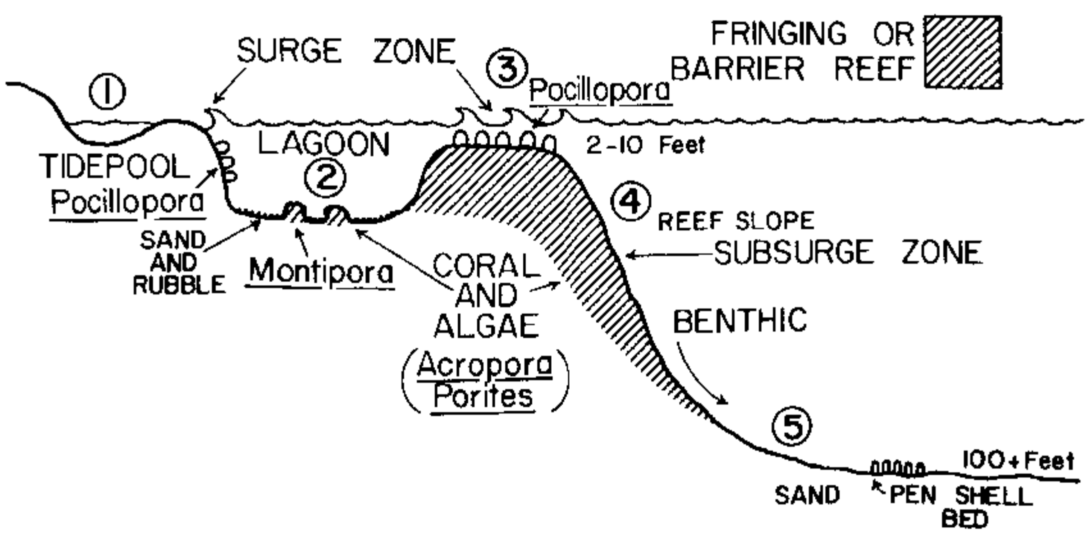


Figure 1. Tropical marine areas which provide specimens for aquaria.

II. INVERTEBRATES AND PLANTS*

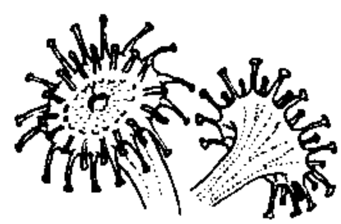
Invertebrates are animals without backbones. They include corals, jellyfishes, snails, worms, sea urchins, crabs, shrimps, lobsters, and many other forms. Because of the number and complexity of invertebrate groups, it is often difficult to identify them. Some of the more common forms are briefly noted here.

A. Invertebrates

1. Jellyfishes, Sea Anemones, and Corals

(Body essentially a sac with a single opening surrounded by tentacles.) Jellyfishes do not make good aquarium animals. The Portuguese man-of-war is the best known of the jellyfishes because large numbers wash up on our beaches from time to time. This species, like all its relatives, has stinging cells on its tentacles which can cause irritation of varying degrees.

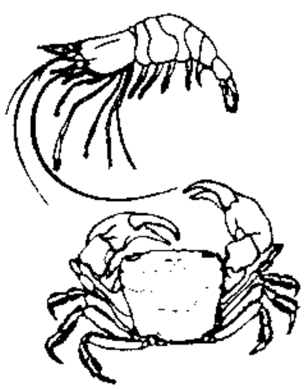
There are three common species of reef corals in Hawaii: *Porites* which forms yellow finger-like encrustations, or solid heads; *Pocillopora* which forms branching heads and is brown in life; and *Montipora* which forms plates or cauliflower-like clumps and is pinkish, lavender, or yellow in life. Maintaining most corals in the aquarium is difficult. The solitary coral *Fungia* or non-reef-building corals such as *Palythoa* and *Tubastrea* are perhaps the easiest to keep. General requirements for corals and sea anemones are sunlight and good water circulation in the tank. (In order to find the best spot for corals, place a sea anemone in your tank and determine where it finally anchors itself, then put the coral in the same spot.) Corals should be collected in plastic bags or buckets and should not be removed from the water. Sea anemones are fairly easy to maintain in the aquarium. They should be fed only twice a week with small pieces of fish or shrimp.



*For further information consult references 7, 13, 15, 21, 25, 32, 35, 36, 37, 45, and 48.

2. Mollusks: Clams, Snails, Nudibranchs, Octopus

(Body with a muscular foot generally used for locomotion, folds in the skin called a "mantle", and often with a shell.) Mollusks for the most part are easily kept in the aquarium once one is able to determine their food habits. (See NUTRITION.) Most mollusks can be collected easily. However, cone shells can sting with venomous darts; therefore collect these animals with care. Cone shells feed on either invertebrates or fishes, so do not place them with prize specimens. Some Nudibranchs can secrete a poison which may kill the other inhabitants of your aquarium. Some of the interesting mollusks that may be kept in the aquarium are the cowries, which feed mainly on algae; basket shells, and octopi which feed on fishes, crabs, and shrimp; and clams which are filter feeders and help maintain water quality.



3. Shrimps, Crabs, and Lobsters

(Body encased in a rigid, armorlike, jointed covering.) Small shrimps, crabs, and lobsters make fine aquarium animals. They will eat practically any type of animal food presented to them and tend to clean up leftover food in the aquarium. They are easily captured. Watch them in your aquarium carefully; they may capture, or be eaten by, other specimens. Hermit crabs, prawns, snapping shrimp, pebble crabs, and decorator crabs are examples.

4. Sea Urchins, Sea Stars, and Sea Cucumbers

(Body encased in a skeleton of armorlike plates upon which are mounted spines and other projections; arranged symmetrically around a central point; tube feet.) Brittle stars and small sea stars are quite easily maintained in the aquarium where they scavenge unwanted food. The crown-of-thorns starfish contains venom released through its thorns and should be handled with care. Sea urchins, on the other hand, are quite difficult to keep because they need a constant supply of algae on which to feed. Our local long-spined sea urchins (wana) should not be collected by hand, as they have poisonous spines. In Hawaii these urchins are sometimes

found with the shrimpfish (*Centriscus strigatus*) which lives among the urchin's spines. There is also a small blue shrimp which lives among the urchin's spines. Sea cucumbers are generally not good for the aquarium because if disturbed, they tend to eviscerate, producing toxic products.

5. <u>Tubeworms</u>

(Body segmented and encased in a tube, mouth region with tentacles.) These worms can be collected by digging for them in the sand or by collecting small rocks or coral heads to which they attach. Tubeworms are filter feeders or feed on bits of unwanted food and are excellent aquarium animals.

B. Plants

Freshwater plants may be purchased or collected from our ponds and streams. To flourish in an aquarium, they need some natural light or artificial lighting duplicating sunlight. Some Hawaiian limus (seaweed) can also be grown with artifical lighting. If the light source is too strong and the water is not well circulated, green and brown algae will bloom on the sides of the tank. It is best to use a good filter and to scrape the aquarium of unwanted algae regularly. Algae, however, is in no way harmful to the marine aquarium and growths should be encouraged as they help maintain the water quality.

III. COMMON TROPICAL FRESHWATER FISHES*

Figure 2 will help you identify the characteristics in parentheses for each fish group in this and the following section.

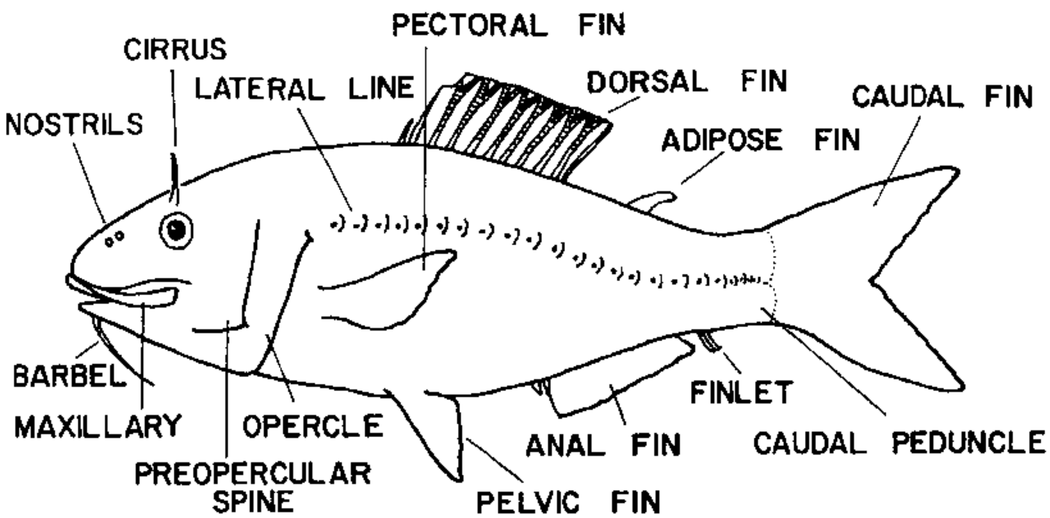
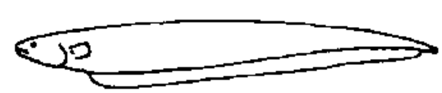


Figure 2. Identifying characteristics of tropical fishes.

1. Electric Fishes (Gymnarchidae, Gymnotidae, and others)



(May have weak or strong electric pulses. In most either dorsal or anal fin is very long and is used in swimming; the posterior end of the body stays rigid. Electric receptors on head.) Most electric fishes are denizens of muddy rivers and use their electric pulses to find food, mates, and shelter. Knife fishes, electric eels, and the elephant nose are examples. Electric fishes are considered difficult to keep in an aquarium. They require peat or black water, plenty of cover, and subdued lighting.

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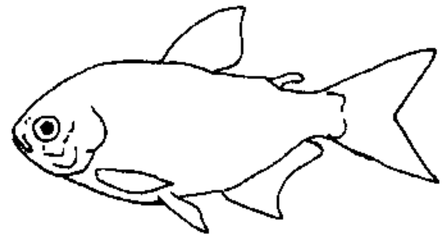
*For further information consult references 5, 6, 7, 17, 18, 19, 30, 39, 44, and 48.

2. Characins (Characidae and others)

(Adipose fin, terminal mouth.) Characins may range in size from the tiny neon tetra to the pacu (3-1/2 feet in length.) Most come from South America where they live in a variety of habitats. One of the best-known characins, the piranha, is not allowed in Hawaii. Most tetras, cave fishes, and vegetable-eating characins may be kept in groups. Be sure to cover your aquarium since many species of this group have a tendency to jump.

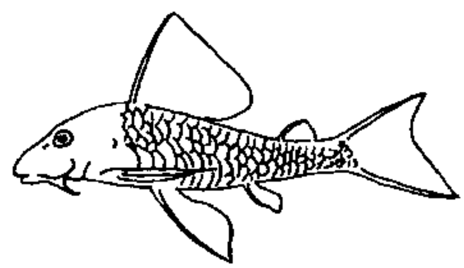


3. Minnows, Loaches, Sharks, Barbs, and Algae-Eaters (Cyprinidae, Cobitidae, and others)

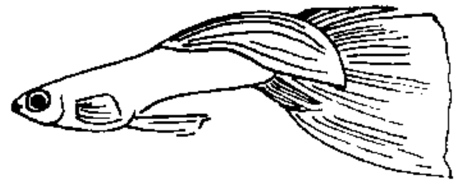
(Terminal or sucker-like mouth, barbels on some.) This group of fishes is also highly diverse, ranging in size from tiny minnows to the 9-foot mahseer. The body shape of these fishes can be eel-like (loaches) or stubby (goldfishes and barbs). Most can be kept in groups.

4. Catfishes (Ictaluridae, Callichthyidae, Loricariidae, and others)

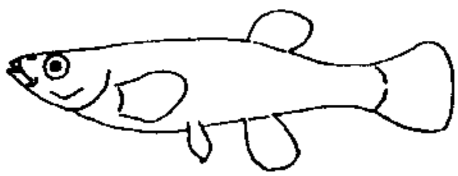
(More than two barbels. Adipose fin. Some with sucker-like mouth.) Catfishes may be found throughout the world. Some are marine, although most live in fresh water. A large South American group is called the armored catfishes because its members have bony plates along their bodies. Other catfish groups are soft-bodied. Catfishes may be kept in groups but tend to become aggressive during breeding. The dorsal spine of the North American catfishes contains an irritating toxin.



5. Guppies, Platys, Swordtails, and Mollies (Poeciliidae)



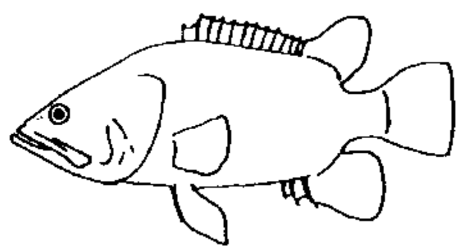
(Mouth turned upward and narrow. Males with a gonopodium.) Members of this group may live in fresh or brackish water. Fertilization is internal, and many varieties have been bred from wild types.



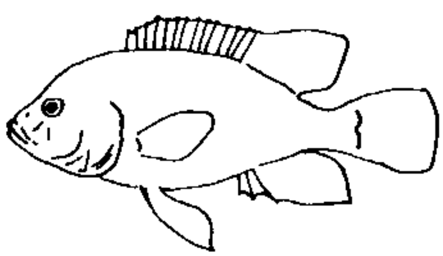
6. Killifishes (Cyprinodontidae)

(Mouth terminal and wide; head broad. Male without a gonopodium.) Many killifishes are able to live in fresh and brackish water. Some species tend to be aggressive and should only be kept in pairs. Killifishes are short-lived, many being annual species. The females are not very colorful. However, the often gaudy coloration of the males makes them attractive aquarium fishes. They are easily bred in captivity.

7. Leaf Fishes and Tiger Fishes (Polycentridae, Nandidae)



(Pointed snout; large mouth. Spines in dorsal fin; continuous dorsal. Three spines in anal fin.) Leaf fishes and tiger fishes are voracious carnivores and should not be placed into a community tank with smaller fishes. However, if several are kept together, they exhibit interesting behaviors such as stalking prey and parental care.

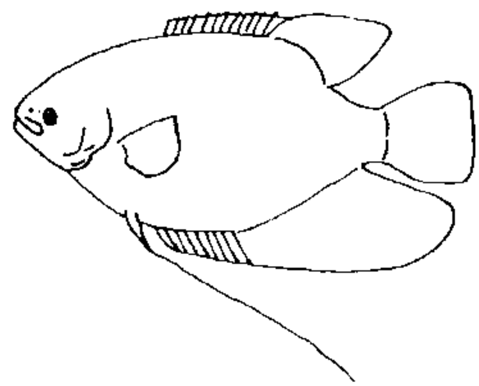


8. Cichlids (Cichlidae)

(Single nostril on each side of head.) Cichlids range in size from the small "dwarfs" to animals reaching 2 feet long. Many, such as angelfishes and tilapias, are easy to keep. Discus fishes are more difficult to handle. All show elaborate courtship and parental care and are an extremely interesting group. Cichlids for the most part should not be kept in community aquaria because they tend to dig up the plants and gravel and chase other fishes out of their territories. Some cichlids are carnivores, and some eat only plant material. Some can live well in fresh, brackish, and salt water.

9. Gouramis and Bettas (Osphronemidae, Antabantidae, and others)

(Often elongate pelvic fins. Many spines in dorsal fin and more than three spines in anal fin.) Gouramis and their allies have an accessory breathing organ so that they can gulp air from the surface. Most are docile. Bettas are well known as the fighting fish of Siam. If two males are placed together, they will fight until one is killed or driven away. For this reason males should be kept alone. Female bettas may be kept in groups.

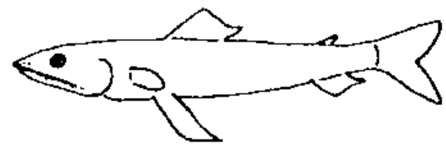


IV. COMMON TROPICAL SALTWATER FISHES*

A. Fish Groups

1. Lizardfishes (Synodontidae)

(Many sharp teeth in mouth. Adipose fin present.) Lizardfishes tend to eat fishes about their own size and are not considered as good community animals. They spend most of their time motionless, buried in or sitting on sand, waiting to dart out and catch their prey.

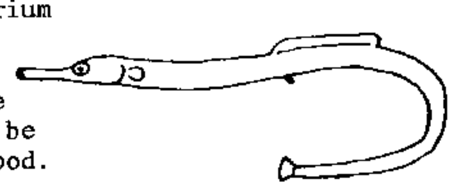


2. Morays and White Eels (Muraenidae, Congridae)

(Long dorsal and anal fins if present. Tubular nostrils. Elongate bodies. No pelvic fins.) Very small marine eels make good aquarium animals, although their aquaria must be tightly covered or they will escape. The commonest of these, the morays, live in holes and are carnivorous. They are easily trained to take food. It is not wise to collect even the smallest moray by hand since its bite, like that of lizardfishes, will often lead to secondary infection.

3. Seahorses and Pipefishes (Syngnathidae)

(Bony plates along body. Snout tubular.) Seahorses and pipefishes are peaceful aquarium inhabitants. Their food habits consist of picking tiny crustaceans from the water or rocks. Some must be fed on live baby brine shrimp or newly hatched fishes; others can be taught to eat bits of dead shrimp or dry food. Because their feeding habits are selective, they are not considered to be fishes for beginners.



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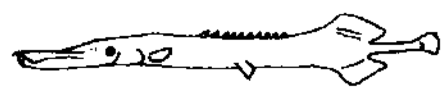
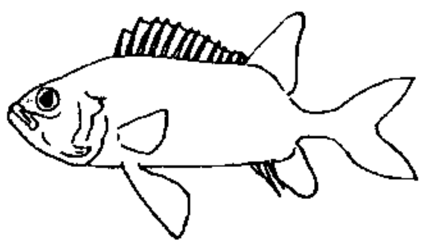
*For further information consult references 3, 4, 6, 7, 10, 22, 25, 31, 33, 36, 39, and 46.

4. Trumpetfishes and Coronetfishes (Aulostomidae, Fistularidae)

(Long tubular snout. Dorsal and anal fins far back on body, which is stick-shaped.) Trumpetfishes and coronetfishes are predators on small fishes. Small trumpetfishes make good aquarium pets if kept alone or with fishes too large to be swallowed. These fish may also be trained to eat dead food. They require a long, large aquarium.



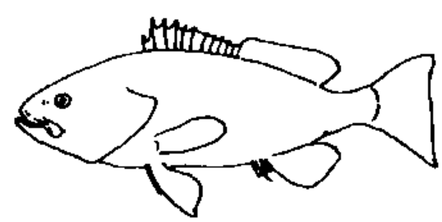
5. Squirrelfishes (Holocentridae)



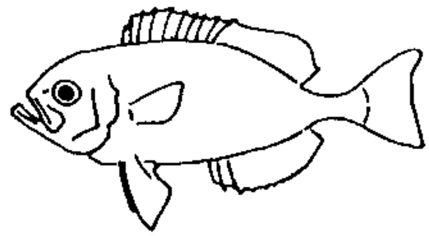
(Large eyes. Rough scales. Body usually red. Anal fin with 4 spines; spines on opercle.) Squirrelfishes readily take bits of shrimp and small fishes. They should be given shelter (caves) because they cannot withstand bright light. U'u or menpachi (soldier-fishes) will live peacefully in groups of their own species in a single shelter. Alaihi (true squirrelfishes) will tend to fight among themselves unless provided with several shelters. Their spines are very sharp, so handle them with care.

6. Groupers (Serranidae)

(Large mouths; maxillary prominent. Body completely scaled. Single dorsal fin with spines; anal fin with 3 spines.) Groupers are peaceful unless their tank-mates are small enough to swallow (about 1/3 the size of the grouper). They live in shelters and will accept bits of dead fish or shrimp. (Some eat plankton in nature and are difficult to feed unless brine shrimp is available.) Some species are highly colorful and remain small.

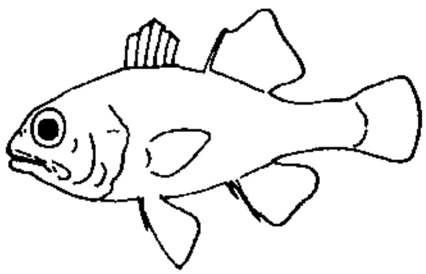


7. Bigeyes (Priacanthidae)



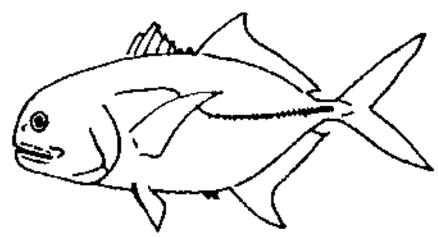
(Eye large. Body red. Small, rough scales. Single dorsal fin with spines; anal fin with 3 spines.) Bigeyes have the same requirements as squirrelfishes. They are peaceful and colorful.

8. Cardinalfishes (Apogonidae)



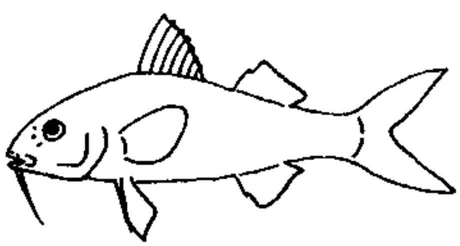
(Large eyes. Two dorsal fins. Anal fin with 3 spines. Maxillary prominent.) Cardinalfishes have similar habits as squirrelfishes, hiding under ledges or in caves during the day and emerging at night to feed. Small cardinalfishes make good aquarium pets and will readily take bits of shrimp and fish. Nocturnal fishes can best be displayed using blue or red lights.

9. Jacks (Carangidae)



(A bony keel along the caudal peduncle.) Small uluas (or papios) make good pets. They are large-mouthed and voracious carnivores and may be fed small shrimp and fishes.

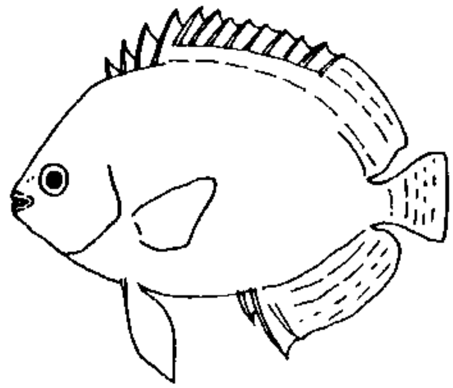
10. Goatfishes (Mullidae)



(Two dorsal fins. Subterminal mouth. Barbels.) Many goatfishes are active bottom feeders, stirring up the sand and probing it for food with their barbels. Outside filters should be used, in addition to undergravel filters, when goatfishes are in a tank. Some goatfishes (such as kumu or moana) feed on small fishes.

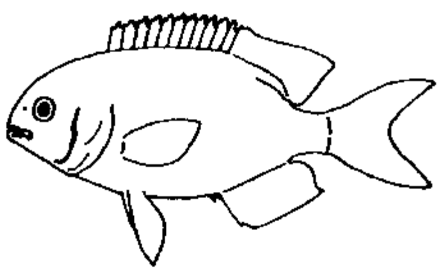
11. Angelfishes and Butterflyfishes (Pomacanthidae, Chaetodontidae)

(High body and spiny dorsal fin.) Angelfishes and butterflyfishes are the most popular of aquarium animals because of their beauty and peacefulness. Many butterflyfishes feed on coral polyps. It is therefore recommended that those with more generalized feeding habits be placed in your tank. These are: *Chaetodon auriga, C. citrinellus, C. fremblii, C. kleini (corallicola), C. lunula, C. miliaris, C. quadrimaculatus*, and *C. unimaculatus*. In nature these fishes and the angelfishes eat algae, coral, and small invertebrates. They may be trained to eat almost everything in your aquarium. Most should be fed plant material. The stripey (Scorpididae) resembles butterflyfishes and is also a good aquarium fish.



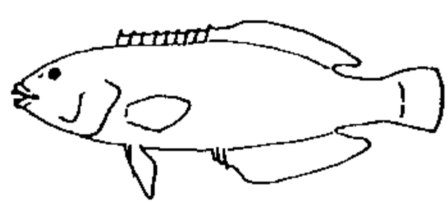
12. Damselfishes (Pomacentridae)

(One nostril on each side; terminal mouth. Single dorsal fin.) Damselfishes are, for the most part, territorial and aggressive in the aquarium. They select a rock or series of rocks in the aquarium and spend their energy keeping other fishes away. Only one or two damselfishes should be kept in an aquarium and preferably two different species (excepting young *Chromis* and *Dascyllus*, forms which aggregate in small groups). Many damselfishes should be fed some seaweed in their diet.



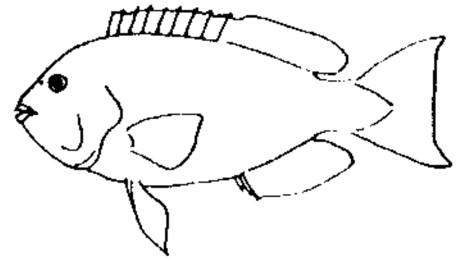
13. Wrasses (Labridae)

(Single, long dorsal fin. Body usually elongate.) Wrasses are peaceful, colorful animals which may be fed a variety of foods. Many need sand in which to bury themselves at night. Most are good aquarium fishes. Exceptions are some of the larger carnivorous forms.

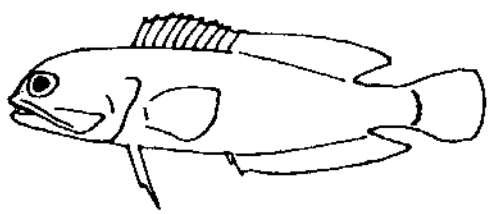


14. Parrotfishes (Scaridae)

(Jaws developed into a beak. Single dorsal fin. Large scales.) Small parrotfishes may be kept in the aquarium if algae-covered rocks are provided. Unfortunately, only the larger Hawaiian parrotfishes are colorful; for this reason, and because they need a constant supply of algae, they do not make good aquarium animals.



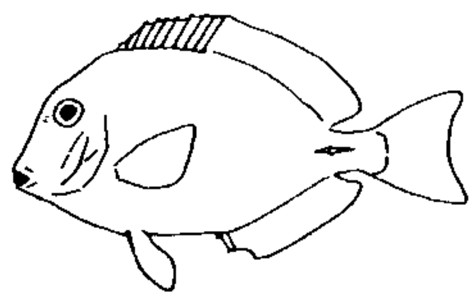
15. Jawfishes (Opisthognathidae)



(Elongate, rounded head with large mouth and eyes.) Jawfishes do not occur in Hawaii, but they may be purchased from time to time. These fishes dig burrows and therefore need a large quantity of gravel. They are colorful, interesting fishes which spend most of their time hovering above or cleaning out their burrows. They are easily maintained in the aquarium.

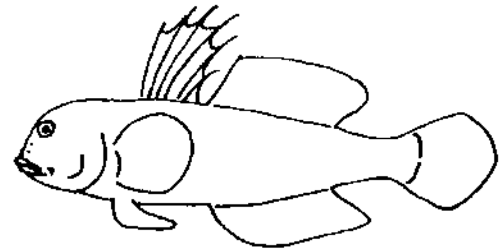
16. Surgeonfishes (Acanthuridae)

(Spines on the caudal peduncle. High body.) Surgeonfishes and moorish idols (Zanclidae) may be kept in the aquarium if plant food is provided. Many will also take flake food. However, the yellow and sailfin tangs (*Zebrasoma* species) need algae-covered rocks or corals for food; otherwise they will not live long. Be careful of the tail region of these fishes which contain knife-like blades.

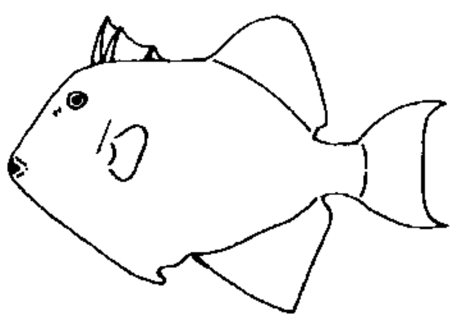


17. <u>Gobies (Gobiidae)</u>

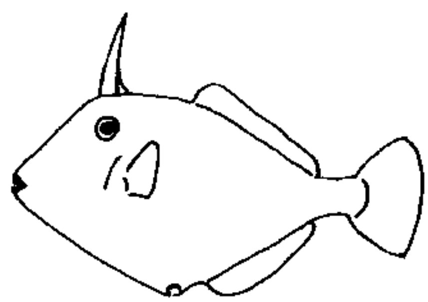
(Pelvic fins fused into a sucking disk. Some forms found in fresh water.) Gobies make attractive aquarium fishes and will eat almost anything. They scavenge in the sand and rocks for bits of food. Some live in holes in the sand and others seek shelter under rocks.



18. <u>Triggerfishes and Filefishes (Balistidae, Monocanthidae)</u>

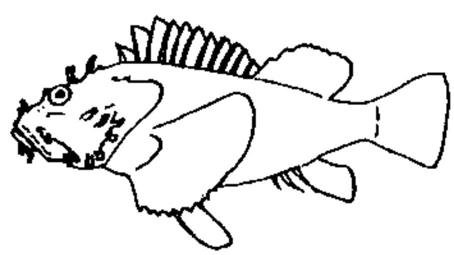


(First dorsal spine separate from the rest of the fin and enlarged. Pelvic fins fused into a bony process.) Triggerfishes and filefishes are hardy animals that can be fed a variety of foods. They tend to be aggressive towards other fishes. They need holes into which they can duck if disturbed. When handling these fishes, take care: they bite.



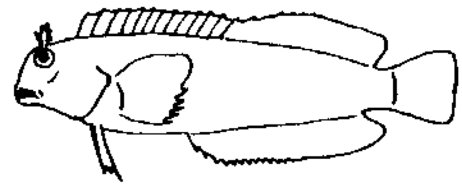
19. <u>Rockfishes (Scorpaenidae)</u>

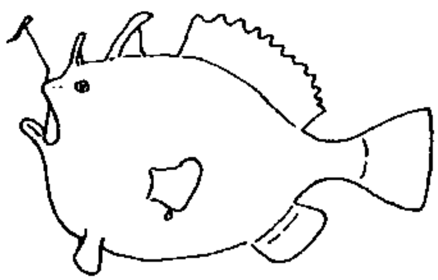
(Long spines on dorsal; large spines on preopercle and opercle. Mouth large.) Rockfishes have habits similar to groupers. The more beautiful ones, the lionfishes, have poisonous spines and are voracious carnivores. They rapidly learn to take bits of shrimp and fish from one's fingers. When feeding lionfish in this manner, be careful of their spines.



20. Blennies (Blenniidae)

(Elongate, single dorsal fin. Cirri on head.) Blennies are often aggressive toward their own kind. One fish per tank is the best solution for preventing fights. Blennies make interesting aquarium pets but should be provided with some plant material in their diet. Often they will take care of this requirement themselves by scraping algae from the glass or rocks.



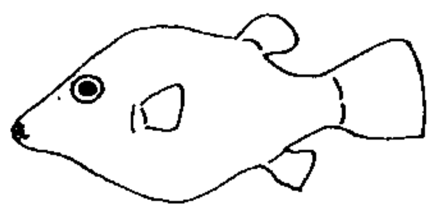


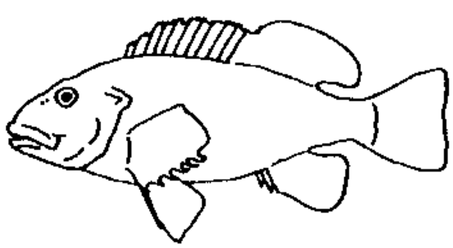
21. Anglerfishes (Antennariidae)

(Pelvic and pectoral fins modified into short, stubby, hand-like structures. A lure near the eye.) Anglerfishes are colorful and interesting, but they feed on live food which they angle with their lure. They require plenty of cover and often do best under natural sunlight.

22. Pufferfishes (Canthigasteridae and others)

(Oval or round bodies with scales modified into bony plates.) If frightened, some pufferfishes secrete a poison which can kill other fishes in the aquarium. For this reason, they do no do well in community aquaria. They readily feed on clams and bits of shrimp.

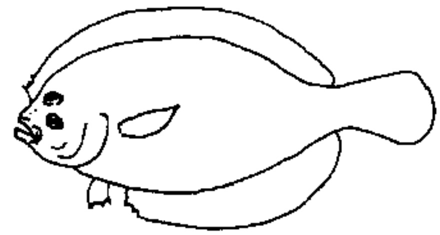




23. Hawkfishes (Cirrhitidae)

(Lower pectoral rays swollen. Spines on body and dorsal.) Hawkfishes have food habits like the groupers and scorpionfishes; they sit on top of rocks during the day rather than under them. They should be kept with fishes no smaller than 2/3 their size.

24. <u>Flatfishes (Bothidae and others)</u>



(Both eyes on one side of the head.) Flatfishes lie on the sand and snap at small crustaceans and mollusks. They will not harm fishes larger than about 2 inches. They make interesting aquarium pets.

B. Hints for Beginners

A general "rule of thumb" in keeping saltwater fishes is to provide 2 gallons of water per inch of fish and an aquarium of at least 20 gallons. However, this rule has many exceptions depending on the filter system. The number and size of the specimens kept depend on the relative temperament of the species; *i.e.*, more small peaceful fishes may be kept together than small aggressive fishes. Most fishes should be of similar size to prevent larger specimens from feeding on smaller tankmates.

It is generally wise to place only one of each species in a tank unless they are paired or are schooling forms. Many fishes tend to be especially aggressive towards others of their own kind. Fighting is minimized if aggressive fishes are unevenly matched and are provided with sufficient space.

The life span of aquatic animals and plants ranges from about one or two days (individual bacteria) to about 100 years (some groupers, coral colonies). Most of the large invertebrates and fishes can be kept in an aquarium for several years. Some, like the killifishes, live for only one year. If the animals or plants in your aquarium die after about six months, usually the deaths occur because one or more of their requirements is missing, rather than from natural causes.

V. BUILDING AND MAINTAINING AQUARIA*

A. Tanks

There are many types of commercial tanks. We advise that you do not use tanks with stainless steel frames for salt water, as they easily corrode. Provide a strong support for your aquarium and use your imagination in designing it. Build your aquarium to fit the area where you wish to place it. Useful unit equivalents for determining the volume and weight of any aquarium are the following:

1 cubic foot of water = 64.2 pounds = 7.5 gallons

1 gallon of water = 3.8 liters = 8.34 pounds = 3800 grams

To calculate how much water an aquarium will hold, multiply the length times the width times the height (in inches), then divide this product by 231. The result is the capacity of the aquarium, in gallons.

Designs for a wooden aquarium and two all-glass aquaria follow.

1. <u>Wooden 100-Gallon Aquarium</u>

Dimensions: 48" long x 24-3/4" high x 23-1/2" deep

Materials:	1 sheet	3/4" AA marine plywood, *plus* enough for 2 braces 46-1/2" x 3" ea
	1 piece	1/4" plate glass, 22-1/2" x 45"
	2 tubes	12-oz clear aquarium sealant (silastic) Do *not* use bathtub sealant; it contains arsenate.
		epoxy resin (enough for 3 coats) *or* fiberglass resin (enough for 2 coats)
	1 box	2-1/2" finishing nails
	1 box	#8 2" screws, flathead wood
	1 box	#8 1-1/2" screws, flathead wood
	1 tube	wood dough
	1 tube	(or 1 can) wood glue

*For further information consult references 11, 17, 20, 30, 31, and 47.

Tools:	drill	claw hammer	saber saw
	screwdriver	saw	paint brush

(Power tools are best for this type of work. You may prefer to have the lumber precut.)

Cutting:	Front and Back	2 pieces 24" x 48"
	Bottom	1 piece 23-1/2" x 48"
	Sides	2 pieces 24" x 22"
	Braces	2 pieces 46-1/2" x 3"

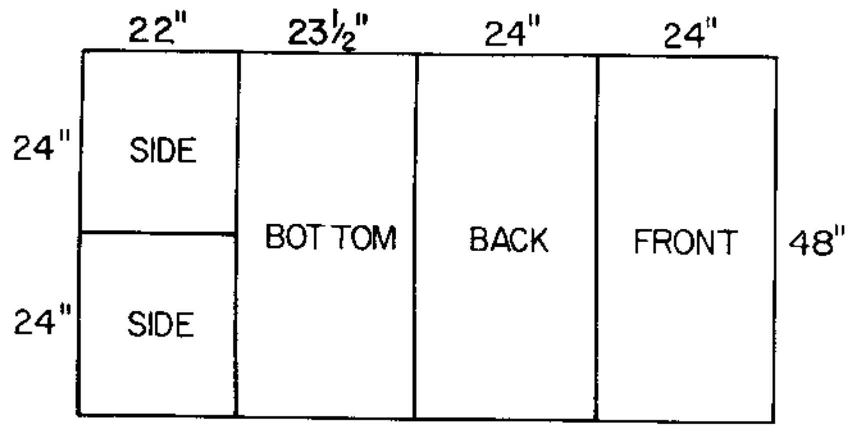


Figure 3. Layout for plywood aquarium pieces.

1. Cut the plywood pieces as shown in Figure 3.
2. The braces may be cut out of the wood removed from the front of the tank if cross braces are desired. We prefer longitudinal braces.

Construction:

1. Put the box together by placing the back and front on top of the bottom and insetting the sides. Hold the pieces together with nails that can be removed (not flush with wood). Apply wood glue to bond all the joining surfaces.
2. Place a mark every 3" to 4" where a screw is to be placed. (See Figure 4.)

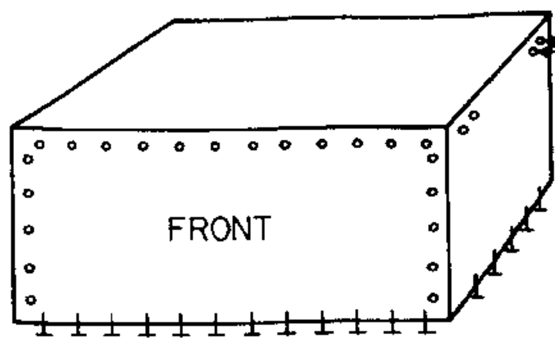


Figure 4. Location of screws for assembling plywood pieces.

3. After the glue in the points has dried, drill holes for the screws. Insert 2" screws alternately with 1-1/2" screws to join the sides and bottom together.

4. Lay out the viewing port, leaving a 3" margin all around *plus* an additional 3/4" on the top for the braces. You may prefer a smaller viewing port, or two ports. Use your imagination here. Cut out the port.

5. Waterproof the inside of the aquarium with either epoxy paint or fiberglass resin. Epoxy comes in a variety of colors and is mixed with a catalyst. It is expensive and three coats are required. Fiberglass laminating resin is also prepared with a catalyst. It may be mixed with colored pigment, or you can paint the box first and then apply the fiberglass resin over it. Two coats are usually enough. Objects such as sea fans, pebbles, posters, etc. can be resined or epoxied into the background. Allow each coat to dry and cure. Read instructions that come with the product you are using.

6. Seal the seams of the aquarium with silastic. To do this, lay a bead of silastic along the seams with the nozzle pointed in the direction of travel. With your thumb, smooth the silastic. Make sure a seal has been created. Let the seal cure for 48 hours. Then put on the final coat of resin.

7. Turn the aquarium over on its front and lay a thick (little-finger sized) bead of silastic around the inside margin of the viewing port about 1-1/2" away from the cut edge of the wood. Then immediately and carefully lay the glass evenly on the silastic. Get someone to help you, so that the glass may be laid down on all points at the same time. Press the glass down and keep it weighted. Don't worry about the excess silastic oozing out; it may be trimmed later with a razor blade. Be sure the seal is solid all the way around. If there are gaps, lift the glass slightly and insert more silastic.

8. Cover the wood frame and glass with newspaper and weight them with bags of sand or building blocks. Let the silastic dry. It will take at least 3 days to fully cure.

9. Screw in the braces. They should also be coated with epoxy or fiberglass. The corners where the brace meets the front and side of the box may be cut away to allow space for airlines and filters. (See Figure 5.)

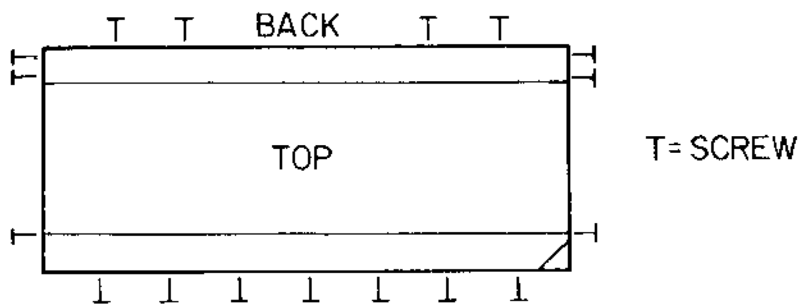


Figure 5. Top view showing brace pieces in place.

10. Paint the outside, stain it, paint it, or cover it with contact paper.

11. This aquarium when full of water, rocks, and sand weighs about 1000 pounds.

2. <u>All-Glass 23-Gallon Aquarium</u>

Dimensions: 30" long x 15" high x 12" deep

Materials:

Plate glass 1/4" thick, as follows:

Front and Back	2 pieces 30" x 15"
Bottom	1 piece 30" x 12"
Sides	2 pieces 11-1/2" x 15"
Braces	2 pieces 2-1/4" x 30"

Have the pieces cut to size and the edges sanded. The glass shop will do this for you. It is cheaper to use used glass for the sides and back of the aquarium. Check

	on new and used glass prices. Plexiglass aquaria may also be constructed by this method; however, plexiglass is very expensive and scratches easily.
1 tube	12-oz clear aquarium sealant (silastic) Do *not* use bathtub sealant; it contains arsenate.
1 roll	masking tape

Construction:

1. Set front, back, and sides on bottom glass.
2. Tape glass together with masking tape on the outside. Make sure it is very clean.
3. Place a solid bead of silastic into corners and along inside edges of aquarium. Press into a solid seal with thumb. Go over edges a second time, a day later.
4. Braces should be glued in place (lengthwise across back and front) after the tank has cured for 12 hours.
5. Allow to cure one week before filling.
6. Trim off any extra silastic with a razor blade after one or two days.

Be sure that the surface on which you set your aquarium is flat; even a sand grain may crack a tank. Cardboard or rubber matting gives it extra protection. For glass aquaria over 12" and under 20" high, use 1/4" plate.

3. <u>All-Glass 10-Gallon Aquarium</u>

Dimensions: 20" long x 12" high x 10" deep

Materials: Double strength window glass 1/8" thick, as follows:

Front and Back	2 pieces 12" x 20"
Bottom	1 piece 10" x 20"
Sides	2 pieces 9-3/4" x 12"

Construction:

Follow the procedure for constructing the 23-gallon aquarium.

B. Aquarium Covers, Hoods, and Lighting

Aquaria should be covered to lessen evaporation and to prevent fishes from jumping out. Covers can be made of glass or plastic. They should be easy to handle. Hoods can contain lights and can be built of lumber or plywood. Stainless steel aquarium hoods and strip lights are available in pet stores. It is generally good practice to place a sheet of glass or plastic between the hood and the tank to avoid corrosion of electrical fittings, especially for saltwater aquariums.

Lighting may be of all types. Daylight or Grolux fluorescent bulbs are the best, since they do not heat the water as much as incandescent bulbs. Side lighting may be used for interesting effects, as well as different colored bulbs. Use your imagination but remember that plants and corals need lots of light, whereas some fishes and invertebrates need darkness. Figure 6 shows a hood with a light for a 100-gallon aquarium.

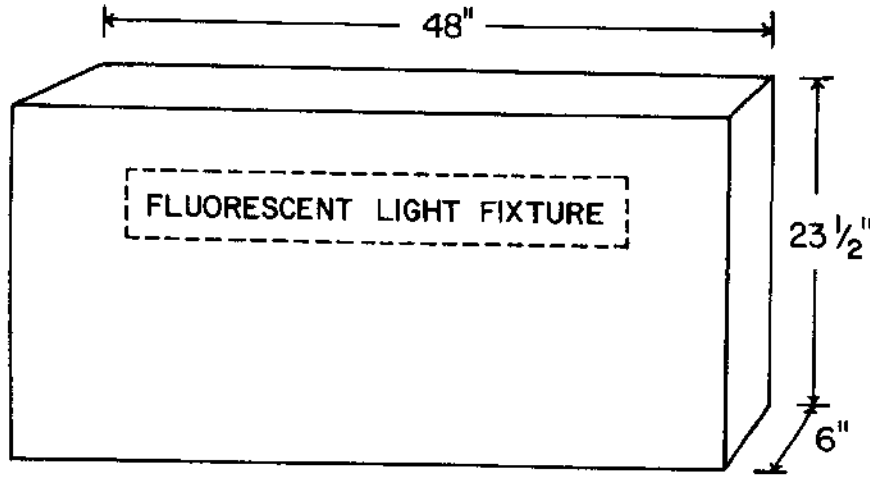


Figure 6. Top view of aquarium hood.

Dimensions: 48" long x 24" wide x 6" high

Materials:

plywood

finishing nails

epoxy resin
or
fiberglass resin

Construction:

1. This hood is most easily made of 1/4" or 1/2" plywood and assembled with finishing nails.
2. It may be hinged at the back onto the aquarium or left free for complete removal.

3. The inside of the hood should be coated with epoxy or fiberglass resin.
4. Bulbs should be placed in the front section so that the light is projected toward the back of the aquarium.
5. The most important point to remember is to protect the light and electrical connections from the water spray.

C. Decor

Use anything that is nontoxic. Ceramic (kiln-fired) or plastic objects, flowerpots (planted or split), driftwood, cleaned coconut shells, or fiberglass moulds can be used in both marine and freshwater aquaria; shells and corals are suitable for marine aquaria. Use objects which will not tip over.

Decor items that are initially or potentially toxic can be prepared in various ways:

- Corals: Soak in 50% chlorine bleach solution for 1/2 hour to a day until they are white; rinse well and place in sun to dry.
- Black coral, sea fans, organ-pipe corals: Soak in fresh water for a day; rinse well, set in desired position out of sun, and dry. Use resin to coat sea fans.
- Shells: Freeze and then pull animal out, or place in 100% pine oil for a week until the animal rots and can be removed. Rinse well. If you have a perfect specimen, remember that water corrodes shells.
- Other objects: Rinse well. If any object smells like dead animals, soak in pine oil or chlorine bleach solution, rinse, and dry in the sun until the smell is completely gone.

The airlift tubes of undergravel filters and the siphon tubes of outside filters can be camouflaged using silastic sealant to glue on pieces of coral and rock to the tubes. The red pipe organ type coral works especially well.

D. Introduction of Animals and Plants

Test your aquarium by putting one or two animals in it for about a week.

Plants can float in the aquarium until they develop roots or can be planted immediately, depending on the species. Dig holes in the gravel, place the plants in the depressions, and cover the roots with gravel up to the crown. Do not pack the gravel. Seaweeds should be attached to rocks. Isolate these rocks and collect the unwanted invertebrates in them. Then place the seaweed-covered rocks in your aquarium.

Invertebrates and fishes should be acclimated to the water of the aquarium. Float the animals in a jar, adding aquarium water a little at a time.

E. Introduction of New Fishes Into an Established Aquarium

Once an aquarium is well established, it is often best to let it remain as it is. If you wish to add fishes, the following procedure is generally recommended:

1. New fishes should be adjusted to the aquarium's temperature and water quality. Float them in a container in the aquarium. Slowly add aquarium water to the container. Net the fishes into the aquarium.

2. Since many fishes are territorial, if a new fish is added the others in the tank may attack it. Rearrange all the decorations and aquascapes. This essentially puts all the fish into a new environment.

3. Feeding the fishes helps divert the old occupants' attention. Generally new fishes will not eat at first, and this gives them a chance to establish residence.

4. After the fishes have eaten, the lights should be turned out. The fishes will settle down for the night, giving the new fishes an opportunity to adjust to their new surroundings.

F. Maintenance of the Aquarium

1. Daily Care

Daily maintenance should include all the following:

1. Count the animals and watch corals and plants for signs of disease and deterioration.
2. Observe water clarity and smell.
3. Watch the behavior of fishes and invertebrates: whether they hide in corners, are fighting, or are listless.
4. Siphon out uneaten food and debris from the tank.

2. Periodic Care

Every 6 months either (1) completely "break down" the tank and clean it or (2) clean it with the fishes and aquarium water still present.

1. Breaking down the tank should proceed as follows: Remove the living organisms and at least 1/2 of the water and put them into an aerated holding container. Remove and clean the rocks and corals with a brush. If the corals are not white, put them in a chlorine bleach solution and rinse them well with running water. Put the gravel into a bucket and wash it thoroughly in running water until clean. New gravel must also be washed. Scrape algae from the aquarium with a sponge, plastic scraper, or plastic pad. Drain but leave a little muddy water in the bottom, in order to produce a new colony of bacteria more quickly. (See FILTRATION.) Scrub filters and replace filter medium. Add the old water until the aquarium is half full, to avoid shocking the fishes due to a sudden change in water quality. Add the new water slowly over a period of a few hours.
2. Cleaning the tank should proceed as follows: Remove all coral and rocks from the aquarium and then clean. Depending on your filtration systems, siphon the gravel into a bucket and clean, or stir up the gravel allowing an outside filter to remove the particles. Scrape or wipe the glass, filter stems, and plastic tubing. Replace rocks and gravel and clean the outside filter.

G. Important Hints

Nets, scrapers, sponges, etc. should be used only in aquaria, not for other purposes. A duplicate net should be used if you have a second aquarium, or these items should be dipped into strong antiseptic solution such as methylene blue. This prevents contamination between aquaria. Wash your hands and rinse them well before putting them in a tank.

Do not use soap or detergent in a tank or on objects put in a tank; they are toxic to fishes and invertebrates.

Do not use metallic objects in the aquarium.

Do not paint an aquarium with anything other than fiberglass or epoxy resin.

Do not add new fishes to an established aquarium. Quarantine them in a separate container for at least two weeks.

Periodic syphoning to collect debris which accumulates beneath the undergravel filter plate can be simply done by hooking the syphoning hose to the filter stem.

As you syphon out old water, slowly add new water at the same time to avoid shocking the animals with a rapid water change.

VI. WATER CHEMISTRY*

Seawater, away from shore, has almost the same chemical composition the world over:

Ion	Concentration (g/kg)
Chloride	19.00
Sodium	10.56
Sulfate	2.65
Magnesium	1.27
Calcium	.40
Potassium	.38
Bicarbonate	.14
Total	about 35.00

This total represents over 99% of the dissolved substances in seawater. The remaining 1% includes a little bit of almost everything else, including dissolved gases. Fresh water contains dissolved substances in very low concentrations.

As water becomes confined in a bay, or in an aquarium, its composition changes, largely as a result of increased biological activity. Dissolved phosphorus, nitrogen, and organic compounds increase, and oxygen tends to decrease. In extreme cases sulphate ions (SO_4^{-2}) lose their oxygen and poisonous hydrogen sulphide (H_2S) is formed.

Marine fishes have evolved to live in seawater of the composition shown above. Any significant changes in this composition will result in sick or dead fishes. Different freshwater fishes are adapted to the water condition in which they are found. Deviations from these conditions are harmful to them.

A. Salinity

The average salinity (total dissolved salts) of open ocean water is about 35 g/kg, with a range of about 33 - 37 g/kg (specific gravity 1.025 with a range of 1.023 - 1.028 as measured by your hydrometer). Pure water has no dissolved salts (0 g/kg; specific gravity of 1.000). The range in salinity results almost exclusively from the addition or loss of water; thus the ratios of the elements remain constant.

*For further information consult references 11, 17, 20, 24, and 43.

Most fishes are adapted to a small range of salinities. The cells of fishes and many invertebrates contain more concentrated salts than are present in fresh water, but less concentrated salts than in salt water. They therefore have special mechanisms with which to bring in or excrete water, depending on where they live. Most of this is done through the gills. However, some fishes such as sharks accumulate urea in their bodies so that they have as high an osmotic pressure as their surroundings. Beyond the limits of tolerance, the fishes' cells become stressed or are killed by osmotic pressure. If a fish, or cell, is put into water that is less salty than normal, the cells will take up water from the outside in an attempt to equalize the salinity on both sides of the cell membrane. This causes them to expand or burst. Conversely, if fishes are put in too salty water, the cells will pass water to the outside to equalize the salinities, and will therefore shrink.

Some fishes have high tolerances to salinity changes; others have small tolerances. Furthermore, the rate of change is important. Rapid changes are commonly more damaging than slow changes. The "grand champion" osmoregulator is the killifish *Fundulus* which can tolerate a salinity range from 0 to 200 g/kg.

B. Oxygen and Carbon Dioxide

Most invertebrates and fishes breathe by removing dissolved oxygen (O_2) from the water by means of gills. Some of the smaller invertebrates and plants, however, can obtain dissolved O_2 directly through their skin. O_2 combines with the carbon atoms in the tissues of animals and plants to produce energy and carbon dioxide (CO_2). CO_2 then passes out through the gills or skin. Consider simply a fish in a tank of water. It is metabolizing and respiring. A generalized equation describing this is:

$$O_2 + (CH_2O)^* \rightarrow CO_2 + H_2O \rightarrow H^+ + HCO_3^- \qquad (1)$$

$$\text{oxygen} + \text{fish} \rightarrow \begin{matrix}\text{carbon}\\ \text{dioxide}\end{matrix} + \text{water} \rightarrow \begin{matrix}\text{hydrogen}\\ \text{ion}\end{matrix} + \begin{matrix}\text{bicarbonate}\\ \text{ion}\end{matrix}$$

Thus O_2 is consumed, CO_2 is increased, and the pH is decreased, resulting in acid water.

Most plants take in carbon dioxide (CO_2) and water (H_2O) from which they produce tissue in order to grow larger or to reproduce. (The process is called photosynthesis.) Plants must have light to provide the energy for photosynthesis. For this reason plants are usually not found in water deeper than about 100 feet.

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*A generalized formula for organic matter.

Consider a fish and some plants in a tank. The fish is as in (1) and the plants are photosynthesizing. The equation describing photosynthesis is:

$$H^+ + HCO_3^- \rightarrow CO_2 + H_2O + \text{light} \rightarrow (CH_2O)^* + O_2 \qquad (2)$$

When photosynthesizing, plants produce O_2 and consume CO_2. The pH rises, resulting in alkaline water. If (1) = (2), the tank is in balance.

All animals and plants must get rid of their body wastes. Unwanted gases like CO_2 are excreted in the process of respiration. With tiny animals or plants, unwanted chemicals are excreted through the surface of the body. However, larger animals have developed kidneys or kidney-like structures to get rid of harmful products such as nitrogen (N) and phosphorus (P) compounds. They also excrete waste products from their digestive tracts. The food must now be considered to be more complex: we can call it (CH_2ONP). Excretion or decay of this food consumes O_2, as in (1), and produces dissolved organic compounds -- which we can call (CHN) and (CHP). These will be considered later.

As the O_2 continues to be depleted toward zero, microorganisms requiring O_2 must get it from an alternative source, notably SO_4^{-2} which is quite abundant in seawater. So instead of H^+ ions simply reacting harmlessly:

$$4H^+ + O_2 \rightarrow 2H_2O \qquad (3)$$

they react with the SO_4^{-2}:

$$SO_4^{-2} + 10H^+ \rightarrow H_2S \text{ (poisonous)} + 4H_2O \qquad (4)$$

Reaction (4) is helped along by the increased amounts of CO_2 produced by the decay, by producing H^+ ions, further decreasing the pH. The reactions that produce H_2S can occur anywhere in the tank, but are most common in the sediments where the O_2 can be rapidly depleted. Black sediment in the aquaria that smells like rotten eggs contains H_2S.

In Hawaiian waters dissolved oxygen is about 5 ml/l. (In cold, well-circulated water it may reach 9 ml/l.) Anoxic conditions and H_2S formation are reached when this concentration drops to 1/2 ml/l.

In aquaria or in natural environments the surface area and the rate of water movement across the surface limit the amount of dissolved oxygen in the system. This is one of the principal reasons for having a filter attached to the aquarium. Bubbles do not add O_2 if there are already normal amounts present, but they are efficient in bringing old water to the surface.

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*A generalized formula for organic matter.

Under some conditions animals can receive too much O_2 and become embolized if the water becomes supersaturated with air bubbles. They can also get the bends if gases are forced into them under pressure, *e.g.*, if they live under a waterfall -- a rare occurrence.

Dissolved oxygen test kits on the market are modified Winkler tests using colorimetry. Colorimetry is simply the use of indicator dyes which change color depending on water quality. The color of the dye is then (1) compared with a set of standard colors each labeled to indicate a specific measurement of water quality, or (2) changed by adding a solution. The number of drops of solution which cause the change in the dye is listed on a table opposite a specific measurement of water quality.

C. pH

$pH = -\log_{10} H^+$ which means that pH is equal to the logarithm of the reciprocal of H^+ concentration. Remember that $\log_{10}$ means the concentration is increased 10 times for every pH unit. Neutral water has a pH of 7. All values under 7 indicate acid water; all values above 7, alkaline water.

Both marine and freshwater organisms tolerate a range of pH; however, most require a pH that lies between 6 and 9. When too much food is placed in the tank or when too much O_2 is used, the pH decreases [Equations (1) and (4)] and when the plants produce O_2 the pH increases [Equation (2)].

pH may be tested with a variety of kits and may be raised or lowered by the addition of acid or alkaline buffers. If you wish to change the pH in your aquarium, add these buffers slowly over a period of at least a week. Abrupt pH changes kill aquatic organisms. We suggest pure peat moss for decreasing pH and sodium bicarbonate (baking soda) for increasing it. Peat may be placed in the tank or filters directly.

The optimal pH in salt water is 8.0, with a range of 7.4 - 8.4. In fresh water pH may vary much more: from 4.0 in parts of the Amazon and Congo Basins to 10.0 in hardwater lakes (Southern California, Sahara Desert). Make sure you know where your freshwater fishes come from, so that you can adjust the pH in the aquarium. Many fish books give this information.

We recommend test kits using creasol red (color-sensitive range 7.2 - 8.8) for salt water and phenol red (range 6.8 - 8.4) for fresh water.

D. Hardness

In limestone areas the lime ($CaCO_3$ and some $MgCO_3$) combines with fresh water and carbon dioxide to form bicarbonate and vice versa. The amount of $CaCO_3$ or $MgCO_3$ in the water determines hardness. Soft water contains 0 - 50 ppm salts, hard water 200+ ppm. Hawaiian fresh water is usually soft. Freshwater animals tolerate varying degrees of hardness although most are found in moderate to soft water. The hardness of seawater is over 4000 ppm, so we do not worry about this factor in marine aquaria. Three hardness units are used by aquarists ppm, °Clark, and °DH. The conversion constants are as follows:

			ppm	°Clark	°DH
(Universal)	1 ppm	=	1.0	0.07	0.056
(English)	1 °Clark	=	14.3	1.00	0.8
(German)	1 °DH	=	17.9	1.25	1.0

Many hardness testing kits can be purchased locally. We recommend the commercial test kits which use EDTA (ethylene-diamine-tetra acetic acid), ammonia, and a bottle of indicator solution.

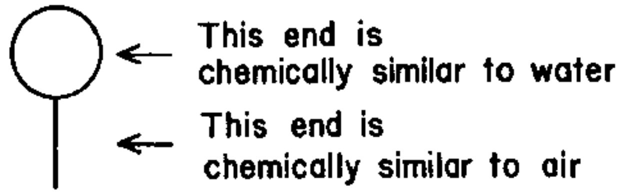
If the water is too hard, you can add distilled water, rainwater, or exchange resins to remove the Mg and Ca from the water. This latter procedure must be done with care or the pH will decrease.

E. Dissolved Organics (CHN, CHP)

The nitrogen- and phosphorus-containing dissolved organic compounds -- ammonia, amino acids, peptides, fatty acids, fatty alcohols, etc. -- produced from the decay of fish foods and the metabolism of animals can be directly poisonous to aquarium fishes because they build up to levels far beyond those found in natural environments. These toxic products can be removed by using charcoal filters, skimmers, or bubblers. Their removal can be entirely beneficial, or to some extent detrimental.

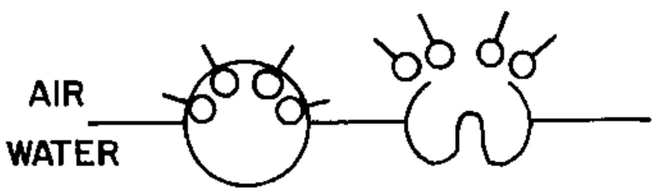
Most of the (CHN)* and (CHP)* molecules produced in the aquarium are polar (*i.e.*, electrically charged) -- not unlike detergents. They can be schematically represented as shown in Figure 7a. Their preferential position in an aquarium, or in the natural environment, is at the air-water interface, as shown in Figure 7b. As the concentration of

*Generalized formulas for molecules containing carbon, hydrogen, and nitrogen or phosphorus.

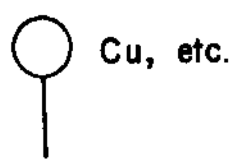


(a) Model of a (CHN) or (CHP) molecule.

(b) Orientation of model at the interface.



(c) Two stages in dispersal of organic film by bubbles.



(d) Trace metals such as copper attach themselves to polar organic molecules.

Figure 7. Models showing orientation and behavior of polar molecules at the air-water interface.

these compounds increases, the whole surface of the water can become a skin of organic compounds. As a bubble passes through the surface of the water, an organic-rich film is formed; with the bursting of the bubble, the organic film is shot into the air. The droplets are so small that they are carried away by any air movement. The process is diagrammed in Figure 7c. Skimmers remove this organic layer in the same manner.

F. Metals

Metals such as copper, zinc, iron, manganese, and cobalt have both positive and negative effects on marine systems. Basically they are to be avoided, but on the other hand, they are necessary to all organisms in small quantities. In aquatic environments metals are usually brought to the water as dust or silt, and are either rapidly complexed with organics which aggregate and settle, or simply settle as dust. Thus, they are continually removed from the water to the bottom sediments.

In an aquarium system with metal parts (except perhaps titanium), the metals can build up very rapidly in the water and become lethal. On the other hand, in a totally nonmetallic system metals can become too low in concentration, which is equally detrimental to the fish and plants.

Trace metals, in small quantities, are most commonly attached to polar organic molecules, as shown in Figure 7d. Thus the mechanisms of removal of the organic molecules are also mechanisms of removal of metals. Bubblers or skimmers will remove these materials. Filters containing activated carbon will remove them temporarily. However, if filters become biological in their activity, the metals will then be continually recycled as the microorganisms break down the organic molecules. Biological filters are perhaps the best way of keeping your aquarium in balance, since the microorganisms within them not only oxidize nitrites, ammonia, and other toxic products into beneficial compounds, but the required metals do not leave the system.

VII. FILTRATION*

A. Airlift Filtration

Pumped air is diffused through many holes in an airstone and is injected into the water as large numbers of small air bubbles. The resultant mixture of air bubbles and water is lighter than water and floats to the surface. As the air bubbles break at the surface, the water mass regains its original density and sinks to replace new air-water mixtures moving toward the surface.

The efficiency of an airlift filter can be increased by decreasing the size of the bubbles and increasing the number of bubbles, thus making the air-water mixture even lighter. Wooden air diffusers give the best results. Also, the longer the filter stem, the more air bubble-water contact time. This produces relatively faster filtration.

Too much aeration is harmful. Suspended masses of bubbles in the water can enter a fish's gills, causing damage. Heavy aeration of the water may lower its specific gravity. If the air is suddenly turned off, the fish may suffer from a rapid increase in specific gravity.

1. Corner Filters

Many commercial models of corner filters are available. They are basically similar in principle. A typical model which can be homemade is shown in Figure 8.

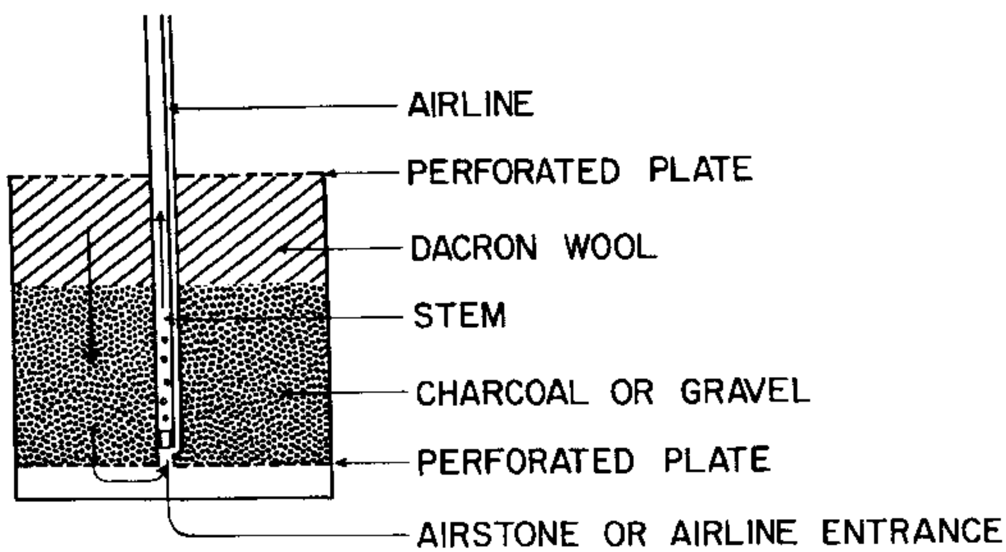


Figure 8. Corner filter.

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*For further information consult references 11, 17, 20, and 43.

2. Outside Filters

There are many commercial types of outside filters. All can be easily cleaned. Filters in which the water intake and outflow tubes are at opposite ends of the aquarium are advantageous because they allow for greater water circulation. (See Figure 9.) The only problem with outside filters is that the water level in the tanks must be higher than the short end of the intake tube.

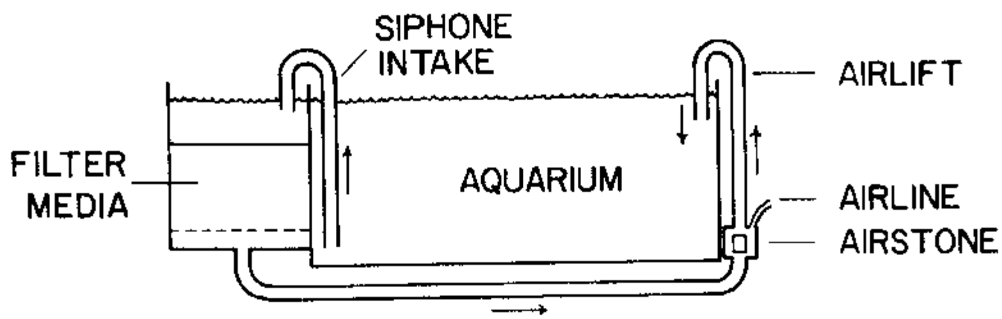

Figure 9. Outside filter with water intake and outflow at opposite ends of tank.

3. Undergravel Filters

Most commercial brands of undergravel filter are equally as good. We suggest that the size of these filters should be at least 1/3 of the aquarium bottom. A two-inch layer of #2 gravel is best, but more can be added. Approximately the top 1-1/2 inches of gravel does most of the filtering, regardless of the total depth of the layer. Undergravel filters should be cleaned every 6 to 8 months.

Once the gravel filter bed has been established, it is important that it should not be disturbed. However, many types of fishes and invertebrates are notorious diggers, causing the gravel filter to become inefficient. When a hole is dug down to the filter plate, water rushes through that particular spot without being filtered. This can be prevented by spreading a layer of gravel one inch deep and covering it with a sheet of fiberglass screening. The screening should then be covered by another inch of gravel. This allows the aquatic animals to dig but also prevents them from upsetting the filter's balance.

An undergravel filter for a 100-gallon aquarium can be made as follows:

Materials:	2 pieces	fiberglass screen, 24" x 48"
	100 lb	aquarium gravel, #2 size
	1	fluorescent light diffusor or "egg crate"
	2	PVC pipes, 1" in diameter and 20" high
	2	PVC elbows to fit the 1" diameter pipes
	2 pieces	plexiglass, 4" x 4" x 1/4"
	2	airstones
	50-100	marbles or pieces of 1/4" outside diameter PVC tubing
		tygon airline tubing
		silastic
		PVC glue

Procedure:

1. Spread marbles or 1/4" PVC tubing evenly over the bottom of the aquarium.
2. Trim and fit egg crate to the inside of the aquarium and place on marbles or PVC tubing.
3. Lay one layer of fiberglass screen on top of the egg crate.
4. Seal the elbows to the PVC pipes with PVC glue or silastic so that the overall heights of the units are 21".
5. Drill holes in the two plexiglass pieces and insert the PVC pipes into them so that the ends of the pipes are flush with the plexiglass. Turn the two pipes so the elbows face the farthest corner of the plexiglass. Seal the pipe to the plexiglass. (See Figure 10a.)
6. Drill a hole in the PVC pipe for the airstone and tygon airline tubing and seal into place. This hole should be about 2" from the base of each PVC pipe. Insert the airstone and tubing as shown. (See Figure 10b.)
7. Place PVC pipes with base attached on the egg crate at either side of the front viewing port.
8. Add a layer of gravel.
9. Place the other fiberglass screen over the gravel.*
10. Add the final layer of gravel.

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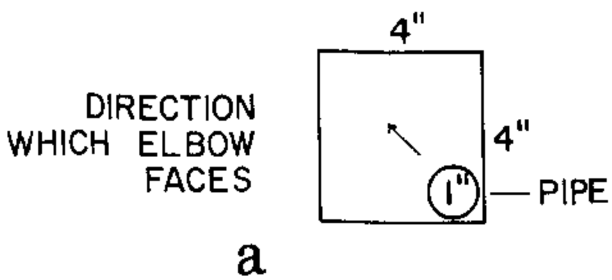
*This layer of screening prevents burrowing animals from digging through the bottom gravel layer when animals that burrow and dig in the sand are present. It is this second gravel layer that is biologically active.



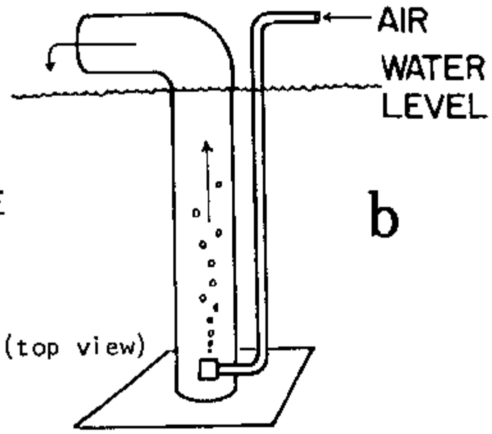


Figure 10. (a) Base for PVC airlift pipe (top view)

and

(b) Airlift pipe with airstone and tubing in place (side view).

4. Protein Skimmers

Although there is no filter medium present, the protein skimmer is designed so that a multitude of tiny bubbles is created. Organic materials and metals adhere to the bubbles. These are carried to the surface in a foam which spills into a collecting dish. Although protein skimmers can be homemade, use and follow the directions for the commercial products before attempting to modify your own. Although commercial skimmers have attachments for an ozonizer, you do not have to attach the latter unit if the sterilizing effect of the ozone is not needed. Cap the ozone attachment or attach two air lines.

5. Combination of Filters

For greater water circulation and filtration, various combinations of airlift filters can be used. Figure 11 is an example.

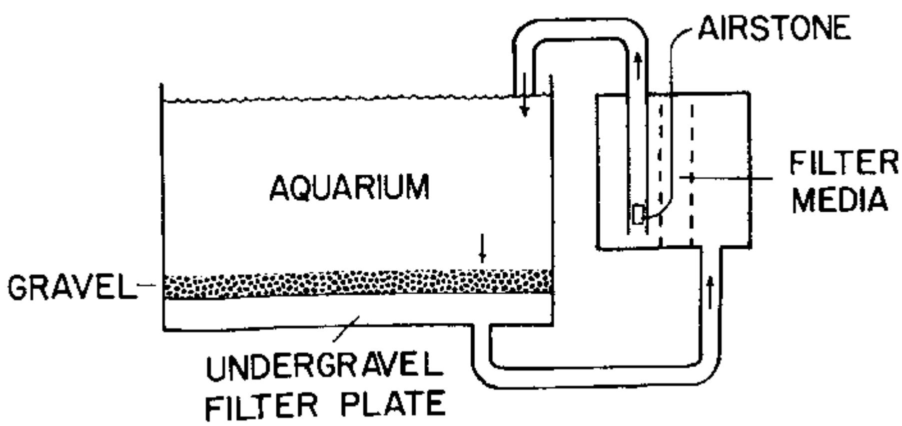


Figure 11. Undergravel filter and outside filter used together.

In this case the undergravel filters remove much of the material. The rest is removed to a closed filter box. This system has several advantages. If the gravel is disturbed, the unwanted substances will be removed to the filter box. The water level can fluctuate. There are no visible filter stems. There is relatively greater circulation and double filtration.

B. Power Filters

Power and diatom filters come with a motor attached which forces water through the filter medium. Rapid circulation is achieved, and cloudy water is initially cleared. Unfortunately, power filters (excluding the diatom filter) have small surface areas. The optimum filter unit should have a capacity of about 1 gallon of water per square foot of filter surface per hour. Therefore, 4.6 sq ft of filter surface would be needed for a 50-gallon aquarium in order to "turn it over" once an hour. Since this type of filtration unit is cumbersome, and biological filtration is not efficient when water is forced through small surfaces at high speeds, noxious gases such as ammonia and small particles are reintroduced into the aquarium. Aeration is usually needed in such a system. The currents produced by power filters, however, are necessary for good coral and benthic algal growth.

The diatom filter is a most useful filter not only for removing suspended particles from the water, but for removing disease organisms from medicated aquaria. Water is forced through bags of diatomaceous earth (a very fine powder to which tiny particles adhere). After use, the filter should be back-flushed with clean water and a disinfectant. Diatom filter bags can be purchased separately. A set of directions comes with each unit.

For more cleaning efficiency the power filter intake can be attached to the air stem of the undergravel filter. The air should be turned off and the power turned on. This will clean out the dirt which accumulates under the filter plate and will increase the time until the next undergravel filter cleaning.

C. Filter Media

When using either outside or inside filters, filtering media must be employed to remove contaminants in the water.

Two media are often used together and the filtered water is returned to the aquarium. Dacron wool is often used to trap large waste particles, which can be subsequently removed or left to be broken down biologically by organisms living in the filter. Activated carbon absorbs toxic gases. Activated carbon decreases in efficiency over short periods of time.

Contrary to assertions of some authors, it can only be partially reactivated if placed in a home oven. It is best to use activated carbon to clear very turbid water. We have not tested the different brands of activated carbon as to their effectiveness.

Filter media include glass wool, Dacron (polyester wool), nylon stockings, cotton or nylon cloth, gravel (dolomite or granite), charcoal, foamed styrene, and diatomaceous earth. For marine aquaria *Halimeda* sand or coarse coral sand is most effective.

D. Biological Filtration

Filter media house organisms which break down and change the composition of potentially toxic products. These organisms include bacteria, worms, and protozoa. Clams, brittle stars, and tubeworms are filter feeders and therefore function like filter media. Many authors and researchers feel that the best filters are those which are biologically active (containing living organisms). When you clean a filter, leave some "mud" in the sand or a bit of old polyester wool so that a new culture of organisms may be established more quickly.

The tiny organisms in filter media cannot break down large pieces of organic material easily. It is sometimes a good practice to put a few snails or crabs in the tank and filter. These scavenge uneaten food.

Living one-celled algae in corals and elsewhere, seaweed, or freshwater plants can serve as biological filters either in the aquarium or in filters. These organisms utilize fish waste products such as carbon dioxide and ammonia, and convert them into oxygen and plant tissue.

E. Pumps

There are numerous types of pumps on the market suitable for running filters in home aquaria. These range in price from about $4 to $400. Vibrator pumps are the simplest and cheapest, whereas larger pumps (piston or rotary) are usually more expensive and deliver more air or water. If water flows through your pump, be sure it is made of plastic and is meant for aquarium purposes. Air pumps should be placed at a higher level than the water in the aquarium so that if the electricity or pump fails, a siphon effect will not occur.

VIII. TEMPERATURE

Tropical fishes should be maintained between 65°F and 85°F. In the literature 70°F is usually given as optimal. We have found that for Pacific marine fishes and most freshwater tropicals 75°F or 80°F is more suitable. Carp and other semitropical fishes can stand wide temperature ranges and fluctuations, but this is not the case for most fishes. It is recommended that even in Hawaii tropical fish hobbyists have heaters in their aquariums because temperature fluctuations, especially in the winter, lead to fish trauma and outbreak of disease. Use heaters with thermostats. In marine aquaria use heaters with no metal parts. We suggest that you use expensive ($6 or more) heater-thermostats as they have a smaller degree of error than the cheaper ones.

IX. ULTRAVIOLET AND OZONE*

Ultraviolet light (UV) produces ozone by cleaving molecules into oxygen and hydrogen atoms. Ozone (O_3) is effective in treating some bacterial diseases, but also will kill useful bacteria and stop biological filtration. In an eight-year study by Steinhart Aquarium, San Francisco, California, it was shown that UV kept the level of bacteria down, but fishes were less resistant to bacterial invasion when the system was shut off. For this reason UV and ozone should be used only for disease control and not in a tank containing healthy fishes.

Too much ozone damages fish gills. UV damages the skin and eyes of animals (including man) and therefore the UV source must be enclosed in a tube or box. If there are any metals in the tanks (even contained in lava rocks, or bronze T-valves) they tend to oxidize and pollute the water. Ozone and UV should be used only in "outside" filters and never where aquarium organisms may contact them. Do not use UV or ozone if fish eggs or larvae are in the aquarium.

There are commercial ozonizers for sale; follow the directions that come with the units. UV units are available and can be homemade. Remember that UV is dangerous.

*For further information consult reference 23.

X. COLLECTING AND TRANSPORTING TROPICAL FISHES

For the saltwater hobbyist who likes the outdoors, fish collecting combines a means of observing fishes in their natural habitats with the personal satisfaction of collecting one's own fishes.

Collecting techniques and equipment are extremely varied; a method successful in a given area or for a particular species of fish may not succeed in another situation. The following is a presentation of what the authors feel to be the most successful techniques for collecting on various substrates.

A. Techniques in Various Areas

1. Coral Reef Areas

Some fishes, like some land animals, are territorial. Within a fish's territory there may be escape routes and hiding places which the collector can observe from a distance without disturbing the fish. If forced to leave its territory, the fish probably will be threatened by other fishes. Therefore, it will attempt to return to its own area as quickly as possible.

The distance within which a collector may approach a fish will vary; this "critical distance" is specific for certain kinds of fishes. One may come closest to fishes living in areas that afford good cover and/or fishes which are cryptically colored. For example, one may approach within several feet of a pipefish causing little disturbance; getting within 10 feet of an Achilles tang may prove difficult.

The manner in which the diver approaches the fish will also influence the fish's action. If the collector moves slowly and carefully, the fish will maintain its critical distance; if the collector makes a rapid, direct movement toward the fish, it probably will either dive for cover or flee. By applying the general principles of fish behavior and by carefully observing both the fish and the area in which it is living, the diver can often outsmart his quarry. For example, place your plastic net in the fish's path, hiding the net's rim as much as possible. Chase the fish until it swims into the net quickly raise the open end of the net upward. Usually the fish swims downward.

Plastic collecting nets may be made in the following way:

Materials:

- frame with handle
- 2-mm thick clear plastic sheeting (type used to upholster furniture)

fiberglass screen (or monofilament mesh)
nylon cord and upholstery needles
thin wire

Procedure:

1. Wrap the plastic sheeting around the rim of the net and cut the plastic to the same length as the circumference.
2. Sew the plastic to the rim as follows: Wrap the plastic around the rim, leaving a margin to be double-folded. The first stitches are to be looped over the rim using a nylon cord. Fold the margin over the rim and sew with wire, looping it over the plastic with each stitch.
3. Stitch the net lengthwise with nylon cord.
4. Stitch the fiberglass screen to the plastic at the bottom and trim. A finished net is shown in Figure 12.

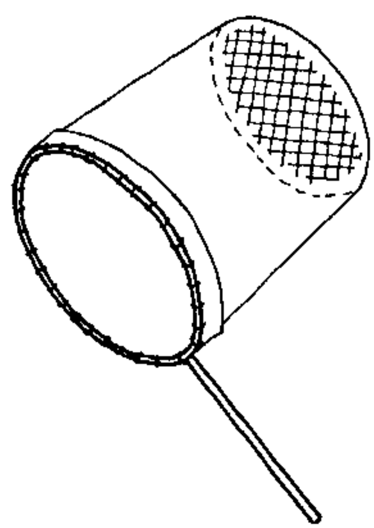


Figure 12. Completed plastic net.

The coral reef is the most difficult habitat in which to collect because it contains many holes and uneven topography, but it is also the home of the widest array of fishes. A drop net (of small mesh size and weighted all around*) serves a useful purpose in covering an entire small coral head in which fishes are seen to hide. This coral head can

*A permit is required in most states to use this type of net.

then be taken to the surface and the fishes shaken out, or the fishes can be prodded into the net without destroying the coral. Corals grow slowly and if they are broken or removed from an area it takes many years before new ones can replace them. Removing coral heads may upset the ecological balance of a reef to such an extent that parts of it may be destroyed.

Some reef areas have beds of coral with finger-like projections that make it very difficult to use a plastic hand net. In such areas monofilament net of the smallest possible mesh size wrapped around a frame of galvanized wire (5-strand) or a cotton mesh net may prove more useful. This net may be constructed in the same fashion as the plastic net. The monofilament net can be moved through the water very quickly and with a bit of luck one may distract the fish with one hand and then chase him toward the net. Do not try to place the net over the fish; you will never catch it. When not in use, block the monofilament net over a 5-gallon bucket to open it up. Eventually it will hold its shape when removed from the bucket.

Another trick is to place a drop net over an area of coral and chase the fish to be caught into the area. Then, as the fish tries to dive into the coral, it is blocked by the drop net and can be caught with a hand net.

A triggerfish may be collected without a net if it is carefully maneuvered into an area having fairly shallow or accessible holes or depressions. It should then be frightened with an abrupt movement causing it to dive into a hole from which it may be removed by depressing its dorsal and anal spines. Care should be taken to avoid being bitten or cut by the spinelets found on the caudal peduncle.

2. Large Ledges and Caves

A ledge or cave area is among the easiest in which to collect. Many fishes which inhabit coral reefs also live near caves or ledges. Usually the rocks are smoother with fewer holes. This makes it easier to collect since the fish often dart under small rocks which can be encircled by a hand net. The tactics are the same as in collecting in any other area.

3. Coral and Rock Rubble

Collecting here is very similar to collecting on a reef. Barrier nets are often used. If you find a small group of patch reefs, set the net in between the reefs. The fish will often run between the two reefs and can be caught in the middle. Fish from both neighboring patch reefs can be collected without moving the barrier net.

4. Grassy and Sand Flats

Grassy and sand flats can be treated similarly when collecting. A barrier net is used to block the escape of fishes. Fishes that live among the grasses are easier to capture with hand nets hidden among the grasses. Sea grasses do not occur in Hawaii.

Attractive, unusual species of sand wrasses are fairly difficult to collect in their own territories. They live over a sand bottom where they can bury themselves when danger threatens. If one can force a fish to move over a rocky bottom or up against a rock ledge, there is a good chance of collecting it. If the fish escapes on the first try, look for it again in about 10 minutes; it probably will have returned to its territory. The trick here is to move the fish toward a hard substrate slowly. Often these animals will dive into the sand and move sideways to the right or left. They may be hand-caught under the sand if one carefully watches them enter the sand.

Many types of gobies and jawfishes that live in burrows are not easily chased from their burrows and then captured. They can be captured, however, using one of two very successful techniques. Dr. J. Bauer, Jr. had excellent success in collecting pearly jawfish in the Florida Keys by digging out the fish's burrows. When the murky water cleared, the jawfish was found over its former home and was easily captured. J. Moore used a barbless hook to take advantage of the jawfishes' behavior. (Jawfish and several gobies will immediately remove any foreign object placed in their burrows.) A small, barbless hook, attached to twelve inches of wire and a nylon leader, was placed in the burrow. Once hooked, the jawfish was quickly drawn up, the hook removed, and the fish placed in the holding container.*

5. Night Collecting

Many fishes rest at night under rocks and in crevices; others come out to feed. If you shine a light on these animals they will "freeze" or behave in a sluggish manner and can easily be caught with a hand net. Fishes in crevices may be pushed from their shelters with a net or a prod. Night collecting is often far easier than daytime maneuvers.

6. Freshwater Collecting

Collecting in fresh water is in many ways similar to saltwater collecting. They differ mainly in the clarity of the water. The waters of rivers and lakes tend often to contain mud and algae in suspension. Diving techniques are then often unsuitable.

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*J. Meyer and O.W. Herald, 1971, "Another Activity of Divers," *Pacific Discovery*, Vol. IX, No. 5.

Freshwater fishes can be collected easily using seine nets made of cotton mesh, with a lead bottom line, floats, and poles at either end for easy handling. A short seine net 4 feet high by 8 feet long is useful in small areas such as streams and ponds. Three people can handle a seine: one works at each end of the net and a third behind the middle, freeing the lead line from stumps and rocks. Walk the net in a semicircle through a shallow area toward shore and drag the lead line to prevent any fish's escape. If no shore is accessible, the best collecting method is to walk the net forward through the water and quickly raise it upward, preferably under some floating plants. Areas of floating plants usually abound in fish life.

When catching fishes with a seine net or with hand nets, wade upstream. You will thereby avoid fishing in stirred-up water and offering the fishes notice of your arrival.

Fishes found in areas of floating plants can be completely encircled using a large net of a bowl or purse type.* The net is manipulated by three people in two boats; one end is secured to a boat and the net is stretched around a floating mass of plants. The bottom of the net is drawn together to create the bowl or purse effect. The whole net is then drawn tighter, and plants are thrown out after inspecting for fishes. If a bowl net is unavailable, a regular seine net will work, as many fishes will not leave their plant cover until the last moment.

Many fishes are easily collected in small ponds or streams using hand nets. Carefully look among the plants and leaves where fishes are most likely to be found. Bait may be offered to attract the fishes.

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To be most successful in collecting, one should be familiar with the area and a variety of collecting techniques. Every situation requires its own modification, so experiment with various ways. If you are collecting in inhabited areas, the local people are the best sources of information on how to collect fishes, especially if they are dependent on fishes for food.

Do not collect more fishes than you can maintain in your aquarium. If you catch too many, throw them back in the area where you collected them. Remember that all fishes are a natural resource. If too many of any species are collected, they will not be available for others to admire and the balance of an ecosystem may be disturbed.

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*This is a method commonly used for collecting fishes on the Amazon and its tributaries.

B. Collecting Equipment

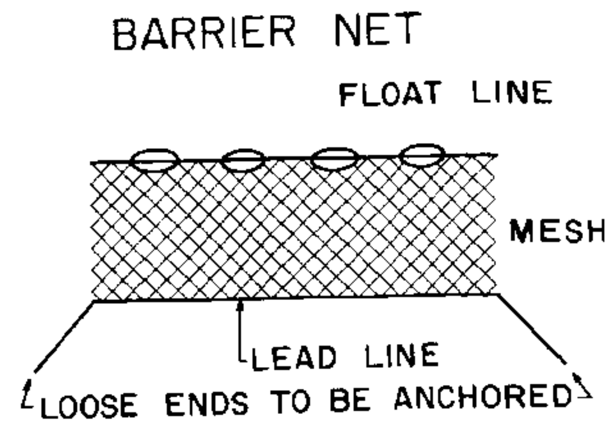
1. Barrier Nets or Seine Nets

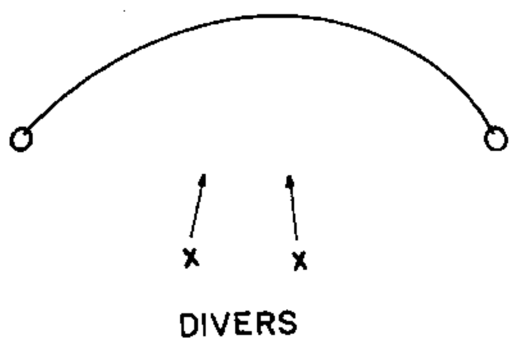
Barrier nets are made of 1/2" or 3/4" blue or clear monofilament 50 feet long by 6 feet high. The bottoms of the nets are weighted with lead lines; the tops are held up by lines of floats. They are set as almost-invisible obstacles in the escape paths normally taken by fishes. Barrier nets work well on sand flats, in coral and rock rubble, and against rock ledges. The use of barrier nets is the most productive method for collecting various butterflyfishes, larger wrasses, and Moorish idols. However, because of the skill needed to handle these nets safely and successfully, they are not recommended tools for an inexperienced collector.

The net is set by two, or preferably three people. One diver takes each end of the net; the third holds the folded protion of the net so it does not become tangled in the coral. The two divers holding the ends of the net move apart and up from the bottom at an approximately 45° angle. Once the net is completely unfolded, the divers move into the desired location and allow it to settle in a semicircle. The ends of the lead lines are secured and all holes along the bottom under the lead line are filled. A few smashed sea urchins in the area of the net may help attract fishes. To avoid disturbing the fishes, the divers either move upwards in the water to a height of about 20 feet above the bottom or swim around the net. Moving together, the divers herd the fishes into the barrier net. The fishes should be scooped up with monofilament, plastic screen, or cotton mesh hand nets because they allow for maximum diver mobility. Fishes that become entangled in the net can be pushed forward through the mesh more easily than pulled backwards. Do not collect any of the fishes that have been damaged in the barrier net.

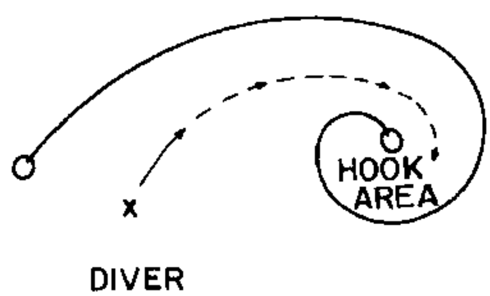
After the desired number of fishes have been taken, the net is gathered up along the lead line. Care must be taken that the net is not torn when freeing it from the coral. It is then tied at both the top and bottom and placed into a bag. (Laundry bags work well.)

If the net is set in a current, divers should work against the current into the net. The net is best layed parallel to the current; if placed perpendicular to a strong current, the current will press the net down onto the bottom. If the diver becomes entangled, it is usually his regulator yoke which becomes enmeshed. To avoid tearing the net, he must either wait for a buddy to free him or remove his tank and free himself. We recommend that the barrier net should not be used in strong surge. Local laws in Hawaii require a permit to use barrier nets of mesh sizes smaller than 2 inches. Permits are obtainable from the Fish and Game Division.





Semi-circular pattern. Net placed in path of fishes or across a reef. Fish are driven into net and scooped up with hand nets.



Swirl pattern. Fast swimming fish will often dart away from the net before the diver can reach it. Here the fish is chased into the hook area where it can be more easily caught. Another diver watching from above can keep the fish from escaping over the float line.

Figure 13. Barrier net collecting patterns.

2. Collecting Jars and Bags

Collecting containers can be made of any convenient material, most often of fiberglass screen, plastic bags, plastic jars, and nylon or cotton mesh.

Plastic or screen bags which are easily tucked into the collector's belt have disadvantages: they are easily torn on coral or pulled loose, allowing the fishes to escape, or damaging the fishes.

Jars have advantages over bags: they are more durable and less cumbersome. Usually more than one fish can be placed in a jar. Only place compatible fishes together. Jars of 1/2- to 1-gallon capacity seem to suit most needs adequately. Screw-top lids should be fastened by string to the jar, and the jar should be fastened to the diver or to a small anchor. Using an anchor relieves the collector of the jars. Jars can also be closed by means of drawstring attachment in which a sleeve of material is fastened around the rim of the jar and tied closely. Several small holes should be punched through the jar, or a hole should be cut in it and a plastic screen glued to it to allow water circulation.

Plastic bait buckets or modified minnow traps with spring latches have been used while collecting from boats and with several divers working in an area. The container can be hung from a boat or can be anchored on the bottom. This is most practical when using a barrier net and is relatively easy to move about. If you are using a collecting jar with a removable lid, remove the lid and place the jar inside the net, gathering it around the jar. Then while you tightly hold the net around the jar's mouth leaving no gaps, have your buddy chase the fish into the jar. Clap the lid over the mouth and secure it.

Another way of transferring the fish is to grasp the specimen gently in your hand and place it carefully in the collecting container. This method is quicker and should be used when the fish are likely to incur further damage for other reasons (*i.e.*, being tangled in a monofilament net). Make sure that you are not injured by the fish spines.

Do not stand on the bottom! It is much harder to get the fish in your holding container if you are fighting to maintain your balance.

3. Slurp Guns

Slurp guns are used in capturing fishes which hide in holes or among the "fingers" of the coral heads and are not easily captured without destroying the coral (*e.g.*, damselfishes and some angelfishes). One simply "slurps" them up with this tool and then puts them into a holding jar. Often the fish are able to swim against the suction of the slurp and escape. It is best to suck the fish head first into the gun barrel and to block the opening. Disadvantages are that the slurp gun is bulky and unwieldy under water and it may injure the fish. It does not lend itself as an all-around collecting tool.

4. Traps

Traps have two main disadvantages: they are nonselective and easily damage fish. Nonetheless, traps often yield a nice selection of tropicals with minimum effort. Figure 14 shows a standard trap design.

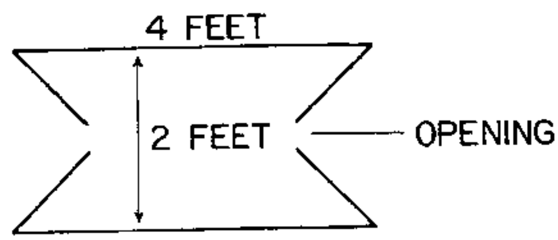


Figure 14. Diagram of typical trap.

The trap is made of a mesh small enough to prevent the escape of the fish of the desired size. The entrance opening may be small enough to prevent large fish from entering.

Sometimes bait (shrimp or fish) is used; it should be wrapped in cloth to prevent captured fish from eating it. Traps should be emptied daily to minimize damage to the fish.

Other objects such as white china dishes may be used to attract fishes. These are useful in areas where eels are plentiful. Eels may smell bait, enter the trap, and eat the fishes.

5. Drop Nets

Drop nets are useful in capturing fishes which dive into isolated coral heads. Once surrounded, the coral head is lifted and the fishes shaken out on the surface. These nets can also be dropped on schools of fishes, used as barriers in uneven terrain, or in conjunction with barrier nets when the substratum contains many holes.

6. Decompressing Fishes

Many fishes must be "decompressed" when brought up from depths of 20 feet or greater, to allow equilibration of the air bladder. For example, bringing a fish such as Potter's angel up from 60 feet at the normal ascent rate (60 ft/min) would cause its swim bladder to expand and rupture, just as a diver's lung would rupture if he did not exhale as he ascended.

Two methods are commonly used to overcome this problem. One is to insert a small (25-gauge) hypodermic needle into the swim bladder of the fish as it is brought up slowly and allow the gas to escape. This has the major disadvantage of possible secondary infection, and requires practice.

The other alternative is to allow the fish to have decompression stops on the way up. This is the best method for the fish, but it is time-consuming for the diver who must either swim up with the fishes or go back and get them at various locations if he is diving from shore. If the fish lose their balance, or if they attempt to swim to the bottom of the container but cannot do so, lower them until they are able to swim normally. Diving from a boat makes decompression easier. The fish are attached to a line hanging over the side which is periodically raised from the boat.

7. Holding Containers

Five-gallon plastic buckets with snap-on lids are convenient shipboard holding containers. Larger plastic garbage cans with lids are used for keeping larger fishes. If many fishes are placed in these containers, it is important to aerate them and partially change the water. Battery-operated air pumps are usually adequate for supplying the needed aeration. Keep the holding containers out of direct sunlight and keep the lids on.

If you are on vacation many miles from your home, bring along several pumps, since only a few fishes should be placed in a single holding container. Each holding container should have an airstone and a rock or other object in which the fish may hide. A partial water change is needed daily.

Do not take more fishes than you are able to keep. You will not only deprive others of observing and perhaps collecting fishes in the same area, but you will end up with many dead fishes.

C. Shipping and Transporting Fish

Whether shipping the fishes by air or in the back seat of your car, the fishes should be packed the same way. Pack the fishes in enough clean water to cover them completely plus a little more. Fill the rest of the container with oxygen or air. Fishes packed with oxygen have to be repacked less often than those packed with plain air.

Do not feed the fish 24 hours prior to shipment. This will minimize excretion by the fish into the shipping water which can easily become fouled. Make sure your bags are sturdy and leak-proof. Each fish should be packed separately in double bags. Lionfishes and other spiny fishes are likely to puncture the plastic bags and should be shipped in plastic bottles.

Foamed styrene boxes are the best containers for packing fishes. These can be obtained at most pet shops which receive them with their fish shipments. The boxes are necessary to prevent rapid temperature changes.

All the smaller bags should be placed in one or two large bags and then into the foamed styrene shipping box. Seal the box securely with masking tape and clearly label it: indicate its contents, which side is up, and a request that it be kept at about 70°F.

For a long trip by car, the fishes should be repacked at least every 12 to 15 hours. Fishes need repacking when their respiration increases. Fishes shipped by air should be packed with oxygen. They can be sent along as excess baggage, or they may be carried on board packed in oxygen or air. If your flight is longer than 15 hours, fishes packed in oxygen should be repacked during your stopover. Fishes packed in air must be aerated more frequently depending on their size and the number of individuals per bag.

When carrying fish on board a plane in a handbag, plastic jars are best. Air changes can be accompanied merely by opening the lid and circulating the air inside by blowing, or by carrying along a battery-operated pump and airstone.

D. State of Hawaii Fish and Game Rules Summarized for Aquarium Collectors

1. You must obtain a permit to collect fishes and invertebrates with small mesh nets (finer than 2").

2. Another permit is required if you intend to sell your animals. Obtain these permits from the Fish and Game Division; you must go there in person.

3. You cannot use chemicals to obtain your animals.

4. You cannot collect animals around Coconut Island, in Honolulu and Hilo Harbors, or in Kealakekua and Hanauma Bays.

5. You cannot take lobster and octopus less than one pound in weight, lobster and large crabs with eggs, the native pearl oyster and introduced oysters, oama (young weke), moi lii (young threadfin), hinana (transparent young of the o'opu of goby), hahalalu (young opelu), or freshwater game fishes.

E. Importation Rules*

You must obtain a permit from the State Department of Agriculture, Plant Quarantine Section, in order to bring living invertebrates or fishes into the state. Private parties may not bring in terrestrial crabs (land, coconut, and hermit crabs), freshwater crabs and crawfish, bowfins, catfishes excepting the channel catfish, electrical eels, garpikes, piranha, sharks, snakeheads, stingrays, stonefishes, and the Australian octopus.

All fishes brought in from abroad must be listed on a customs declaration giving scientific name, common name, number, and approximate size. This is required by the Federal Endangered Species Act. Fishes on the Endangered Species List (Red Book) or protected in the country of origin are prohibited entry (Lacey Act).

We wish to reiterate: do not be greedy. Most marine fishes and invertebrates have not been raised in captivity and there are limited numbers of fishes around our islands. If many people start collecting large numbers of reef animals, our Hawaiian marine fauna will be in danger of extinction.

*Check current importation laws.

XI. COLLECTING AND TRANSPORTING INVERTEBRATES

A. Collecting Invertebrates

Most invertebrates remain under rocks or in the sand during the day. They emerge to feed at night; at that time they may be easily collected. During the day, one must turn over rocks or fan the sand to find them. Make sure you replace each rock in its original position; if it is left upside down, the rest of the animals living there may die or be eaten. Many of the smaller crabs, sea urchins, and mollusks can be obtained by breaking open pieces of rubble. Although these animals will hide during the day in your aquarium, they will emerge at night and clean up extra food particles.

Plastic hand nets are well suited for collecting invertebrates which tend to become entangled in mesh nets. If you are collecting invertebrates by hand, be sure to wear gloves. Invertebrates should not be collected indiscriminately, since many deliver toxic bites or stings or make poor aquarium animals. Collect only small forms which you can maintain in your aquarium.

When collected, shrimp or brittle stars may lose an appendage, but they are capable of regenerating their lost limbs quickly. Therefore specimens damaged in this way are as suitable as undamaged specimens. Banded or striped (red and white) cleaning shrimp are often found in holes with eels, so collect them with caution. Anemones can be found buried in the sand or attached to rocks. They must be removed from rocks by carefully working your thumb underneath their pedal disc and lifting them free. Anemones are also found attached to the shells of hermit crabs or to the claws of one type of crab. Collect both organisms, since the crabs interact with the anemones they have placed on themselves. Some crabs, called "decorator crabs", look like walking gardens. If you collect these, place different types of seaweed in the aquarium and the crabs will place pieces of it on their backs. Small crabs and basket shells may be enticed out of their hiding places by a piece of bait on the sand. Do not collect crabs that swim. They will catch and eat fishes much larger than themselves at night.

Shells are becoming much scarcer in recent years because many people tend to overcollect them. One should always remember that if a living animal is collected, it should be kept in an aquarium and returned to the ocean if unwanted.

Sponges are not easily kept in aquaria; they tend to decompose and poison the water.

Collecting procedures for other invertebrates have been mentioned in Section III.

B. Transporting Invertebrates

The procedures for shipping invertebrates and fishes are similar. Remember that delicate organisms will be injured during shipping if thrown into bags. Fresh seaweed or substitute material may be placed in the bags with some of the invertebrates, so that they can cling to it. Like many fishes, invertebrates such as shrimp and crabs should be shipped in separate bags because they tend to fight.

When receiving shipments of fish and invertebrates open the boxes in subdued light to prevent the aquatic animals from being shocked by sudden bright light. Remove each bag from the shipping carton and place the contents in separate jars for acclimation. Slowly add an equal volume of water (similar to the water in which they are to be kept) to the water in which they were shipped. After they have been acclimated, net the fish or invertebrate into the aquarium. Do not reuse the water in the acclimating jar.

XII. SENSING, MOVEMENT, AND PROTECTION*

Plants and animals must be sensitive to their environment to some extent, in order to avoid predators or adverse conditions. Sense organs or chemical systems help them do this. Plants contain chemicals which cause them to bend toward the light. Some animals have very simple sense organs, whereas animals such as fishes, mollusks, and crustaceans have elaborate ones. Fishes, for example, have eyes and nostrils as well as tactile (touch) receptors and lateral line organs for detecting movement. Some fishes that live in turbid water have receptors for detecting electricity.

All animals are capable of motion. We all know that fishes have fins which propel them through the water and that crabs walk about on their legs. Locomotion or movement in other groups is less well known. Sea stars and sea urchins use the many tube feet projecting from their bodies to move about. Mollusks and flatworms move by contracting and expanding the muscles on their ventral sides. Even sponges move. The interior of a sponge is filled with whip-like cells which beat and create water currents through the sponge. Other animals move in a variety of different ways. Some you will discover on your own, others may be found in the references.

Other than their sense organs, animals have many ways of protecting themselves such as color patterns that conceal them, spines or armor on their bodies, and sharp teeth or beaks. Some produce poisons harmful to other animals. Some have body shapes which allow them to slip into holes or crevices in the reef. With fishes, one important factor is that their bodies are slimy. The slime (mucus) creates a smooth surface which helps them swim and protects their skin from the aquatic environment.

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*For further information consult references 7, 36, and 40.

XIII. SYMBIOTIC BEHAVIOR*

Symbiosis refers to the ways in which animals of different species affect each other. In some cases (*e.g.*, corals and algae) the organisms probably show little overt response to one another; however, in many others the animals concerned interact with one another behaviorally.

An aquarist should take advantage of symbioses in order to have a "healthier", more educational, and more active aquarium. But beware: not all symbioses will work in small aquaria and some may be so altered as to be detrimental to the animals.

A. Camouflage

Camouflage is a reduction in information or clues regarding the location, movement, and identity of an organism.

1. <u>The Factors Involved</u>

Three factors must be considered in order to understand the animal's camouflage.

1. Background or Model: You must know what the organism is trying to match in its natural environment (*e.g.*, a rock, another fish).
2. Animal: This is the camouflaged animal. The camouflage may involve more than color or shape. It may include movement, since all animals move in some way and plants move passively in the surge. To be camouflaged, the animal must match its background or the movement of its model.
3. Third Party: The animal is camouflaged because of this organism (predator, prey, etc.), as protection against it or to catch it. Passive camouflage protection may include active protective devices such as spines or venom; but usually these are "advertised" (involve increased information as to location, movement, and/or identity) instead of being camouflaged. You must deal in the "sensory world" of the third party. What does this party see, taste, smell, etc? Caution: it may not be the same as your sensory world.

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*For further information consult reference 28.

2. Camouflage Behavior

The behavior of the camouflaged animal in nature or in your tank may be the following:

1. The animal may search for its model. If this model is not present in your tank, both abnormal behavior of the animal and inadequate protection for it may ensue.

2. The animal may "track" the available model by changing its color, shape, etc. such as fish altering their chromatophores (color cells) or nudibranchs changing color by ingesting host coral polyps. You should provide a model that falls within the range of their tracking ability. (For example, if you provide black *Tubastrea* coral to some nudibranchs that are red because they have eaten red *Tubastrea*, they will eat their new host and become black.)

3. Relative abundance is frequently critical: with too many animals and too few models, the third party may quickly learn the deception. This is particularly important in mimicry: most aquaria are too small to permit a ratio of mimics to models that is small enough for mimicry to work. (For example, in much of the Indo-Pacific region there is a small blenny that mimics the cleaner wrasse. Instead of picking parasites from the host fishes, it takes chunks out of them. If one blenny and one cleanerfish are put into an aquarium, the other fishes will soon learn to avoid the blenny.)

B. Interspecific Aggression - Territorial Defense

Interspecific aggression means threats or fighting between animals of different species. Territorial defense has been explained. What causes these behaviors? There are two views on the subject.

1. The Lorenzian View (Konrad Lorenz): Morphological (structural) and behavioral similarity result in the greatest aggression. This view is based primarily on aquarium interactions. (For example, two species similar in size, coloration, and body shape will tend to attack each other more often than two dissimilar species.)

2. Ecological View: The species that have the most overlap in their need for limited resources show the most aggression between them. This view is based on field observations. (*E.g.*, suppose there is not enough of one type of seaweed to feed two different species. This view suggests that these two species will attack each other more often than species which do not eat it.)

Interspecific aggression and territorial defense could be a combination of the two views. In the field, resources are limited and the ecological view may be of primary importance. In the aquarium, however, resources should not be limited (unless one crowds his fishes) and the Lorenzian view may dominate. We need more research in this area before we can evaluate the relative importance of these two factors.

Dealing with the Problem

What can we do about interspecific aggression and territorial defense in an aquarium?

1. Enjoy it: It's much more fun to see animals interact than ignore each other.
2. Increase the number of cover items and arrange the aquarium so that there are natural boundaries (*e.g.*, provide sand between rock piles).
3. Keep the number of your fishes constant but increase their morphological diversity (fishes of different species and shapes) and ecotype diversity (fishes from different habitats, such as sand and rubble). In nature some species form mixed schools which enable them to invade the territories of other fishes *en masse*. We do not know whether this happens in an aquarium. To our knowledge it has not been tried. To do so one might collect a school of wrasses, parrotfishes, etc. and place them in a tank with some territory-holding damselfishes.

C. Parasitism - Predation

Whether a species be a predator or parasite in nature, its numbers depend on how many individuals it removes from each host species. The more predatory an organism, the fewer there can be in relation to its hosts. Be sure to balance your tank to allow for this. Feed potential predators enough so they do not attempt to capture other animals in the aquarium, and do not mix large predators with other fishes. Simply feeding predators may not stop them from killing. For example, feeding a cat artificial foods does not stop it from hunting, although it does not eat its prey. This type of behavior may occur with fishes.

Restricted space allows for continued exposure of prey to predator and host to parasite, and can induce more stress on the aquarium than when it is uncrowded. For example, parasites with short life cycles and fast growth rates can reinfect their hosts a number of times.

D. Cleaning

Behaviorally a host fish and cleaner fish signal. (The host usually assumes an abnormal position near the cleaner; the cleaner dances in front of the host or is brightly colored.) The cleaner then moves over the host, touching it and picking off parasites and other material.

The ecological role of cleaning is to remove parasites, but cleaning is not always needed on a reef or in a tank. Though cleaning is thought of as mutualistic (both cleaner and host benefit), it can become parasitic if conditions are wrong. Obligate cleaners (those which die unless provided with parasite food) in waters with few hosts may either starve to death or parasitize their hosts. They may at times "clean their hosts to the bone". Therefore use facultative cleaners (those which eat parasites and other foods) in an aquarium, and provide some alternate food supply.

XIV. SPAWNING AND REARING FISHES*

Every species of animal and plant must reproduce in order that the line be continued. Some plants and some animals such as sponges and flatworms may split into many new organisms. Coral polyps grow by budding off new polyps from the bases of existing ones to create a colony. The male and female of the fishes and many invertebrates pair and produce eggs and sperm. There are many different ways in which these animals reproduce and care for their eggs.

Spawning types in fishes are the main subjects of this section, but the reproduction of aquatic invertebrates is also interesting. For example, after a pair of crabs or lobsters mate, the female may move about carrying the eggs underneath her abdomen and release the young (larvae) into the water when they hatch. The female cowrie and octopus, on the other hand, cover their eggs with their bodies and brood in one spot until the eggs hatch. Sea urchins, corals, tubeworms, and many other invertebrates release eggs and sperm into the water.

There is a wealth of detailed information in the literature on spawning of freshwater fishes. Saltwater fishes, on the other hand, have rarely spawned in aquaria and have seldom been raised. In order to induce marine fishes to spawn, techniques similar to those applied to freshwater fishes of the same spawning type can be employed. One should consult the literature for the environmental requirements of the species you wish to spawn. Replicate the conditions which surround the fish in nature as nearly as possible. For example, species from the Amazon River region have done best in murky water with dim lighting, rather than in normally bright, clean aquaria. Remember, every species of fish can spawn in captivity and does spawn in nature.

A. Recommendations

1. Feed fishes a varied diet and as much food as they will eat.
2. Keep fishes which are ready to spawn in a quiet corner of your home.
3. The males and females of some fishes should be kept separately until they are physically ready for reproduction.
4. Be sure the water quality is that recommended in the literature (similar to the water in the fish's natural habitat).

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*For further information consult references 2, 17, and 44.

5. Keep the lighting subdued; many species spawn most frequently at dawn or dusk.

6. Increasing the water temperature may lead to spawning.

7. Siphon dirt from the tank frequently. Filter the siphoned water and replace it in the tank. Do not filter the water in a tank containing eggs and fry unless the eggs and fry are large, the eggs are attached to the substrate, or there is parental care. Underground filtration should not be used if the eggs are in the gravel.

8. Unless the fry are cared for by their parents, raise them separately. If the adults, eggs, or fry are to remain in the aquarium, many hiding places should be provided. The number of young per pair is usually from 20 to 10,000.

9. If the water, lighting, food, and substrate conditions are proper, every species kept in captivity should spawn.

B. Obtaining Pairs

1. Obtain about six young fish and raise them in order to be sure of obtaining a male and a female. You cannot tell sexes in most marine fishes even if they become sexually mature; however, courtship behavior or a change in coloration may help.

2. Let the fish pair by themselves. In many cases, it is best to remove all fishes except for the pair. Let them spawn, or separate them with a glass and then allow then to spawn when the female is ripe. In some cases spawning is facilitated by other spawning fishes (*e.g.*, some damselfishes, characins, killies, chichlids).

C. Spawning Types

1. Egg scatterers: The male and female usually swim side by side depositing eggs and sperm which either fall to the bottom, stick to plants, or remain suspended in midwater. Neither parent cares for the eggs or fry, and either parent may eat them if given the chance. If the eggs fall to the bottom or adhere to plants, spawning substrates should be used which can either be removed (*e.g.*, spawning mops) or which the parents cannot penetrate (*e.g.*, peat moss, marbles, grates over mud and sand). Eggs which remain in midwater should be removed to culture dishes. Examples of egg scatterers are some killifishes tetras, barbs, and most marine fishes.

2. Substrate spawners: These species hang or anchor their eggs on hard substrates or plants during spawning. Some of these fishes hide their eggs in holes and caves, others may lay them in exposed places. Courtship is usually elaborate. When spawning, the female lays a string of eggs, the male fertilizes them, the female lays another string and so on. Artificial substitutes for natural spawning sites may be plastic plants, slate strips, flower pots, foamed styrene cups, cork, etc. The parents usually care for their eggs by fanning, guarding, and cleaning them, and may guard the fry when they hatch. Examples of substrate spawners are some cichlids, nandids, damselfishes, and gobies.

3. Egg buriers: The eggs are laid in the substratum or on it and buried. The male is usually more colorful than the female. Both sexes either dive into the substratum and spawn or dig out a depression, spawn, and cover the eggs. There is no parental care. The eggs are resistant to drying, so may be removed to a moist dish to incubate. Examples of egg buriers are some killifishes and grunion.

4. Depression spawners: The pair (or one member of the pair) digs out a pit in the substratum. Courtship is elaborate. The pair spawns in the depression and the eggs are either picked up and mouth brooded, attended to in the pit, or ignored by the parents. Egg care and fanning by one or both parents may occur and the fry may be guarded. Examples of some depression spawners are cichlids and catfishes.

5. Mouthbrooders and pouch brooders: Mouth brooding is a special way of attending the young. The male or female usually picks up the eggs from the substratum. (In cardinalfishes, the eggs are transferred directly into the mouth of the male.) Parents may brood up to 5 weeks without eating. When the young hatch they leave their parents' mouth and are either ignored (cardinalfishes and aruanas), are guarded (some catfishes), or are guarded and taken back into the mouth in times of danger (some cichlids). Pouch brooding in the seahorses and pipefishes is another specialized way of caring for eggs. The eggs are laid by the female into the male's pouch where they are brooded. The young are not cared for when they hatch.

6. Nest builders: The males build a nest of bubbles or plant material. With anabantids, bubble nests are built at the water's surface under floating plants by the male. Courtship is elaborate. The male loops his body over the female, allowing maximum contact. A few eggs are extruded, picked up by the male, and deposited under the bubbles. Several spawning acts occur. The eggs are maintained in the nest until they hatch. Provide bubble nest builders an aquarium with water about 4 inches deep and with a cover, for spawning. The female should be removed after she lays her eggs. Foamed styrene may substitute for floating plants. Stickleback males construct a nest of plant material with a hole in it, into which the female is enticed to enter. When she lays her eggs in the nest, they are guarded and fanned by the male.

7. Livebearers: The male fertilizes the female internally by means of a specialized fin (gonopodium) or by fanning sperm into the female with his anal fin. Males are usually more brightly colored than females. They use S-shaped or zigzag motions to position the female for sperm transfer. Either remove both parents when the young emerge, or remove the female to a heavily planted aquarium after mating. Examples are guppies, mollies, swordtails, and halfbeaks.

D. Artificially Raising Eggs and Fry

Many kinds of aquatic plants and animals produce young which look very different from their parents. Larvae of many species spend a period of time in the plankton before transforming into miniature adults. These larvae often have different habits and requirements in the plankton community than in the community where they live as adults. For example, larval surgeonfishes are carnivores, whereas when they transform into adults they become herbivores.

1. Eggs normally receiving parental care should be aerated and moved about with a weak stream of water. However, do not allow the eggs to contact the air or air bubbles. Eggs normally brooded should be rolled, using the force of a thin stream of water. Bubble nests should be removed by placing a shallow dish under them and carefully lifting them out. Young and eggs of substrate spawners should be kept in dim light and aerated. Eggs buried by killifishes should be removed to shallow dishes of water, kept in the dark for 2 to 6 weeks (depending on the species), and placed in water again. Remove fungus-infected eggs immediately. In most cases a mild fungicide or antiseptic may be applied. Temperature and water conditions should remain constant.

2. When the young hatch, wait until the yolk sac disappears; then be sure there is a constant supply of food. Feed at least four times a day. Fishes hatching from large eggs can often feed on baby brine shrimp or daphnia. Smaller fishes (< 5 mm) take plankton, finely ground brine shrimp, microworms, or infusoria. Both will eat cooked egg yolk, tube food, ground dry food, or high-protein cereal. Make sure the food is fine enough to be eaten. Look at the bellies of the fry. If their bellies look swollen, they probably have enough food. Some fishes, such as discus, must be raised by their parents because they feed on special parental mucus secretions. Do not overcrowd the fry, thereby inhibiting their growth. It is best not to place them into a large aquarium at first. The larger the aquarium, the harder it is for the fry to find food. Place the newly hatched brood into a 3- or 5-gallon aquarium. As they grow, they can be separated into several aquaria or placed into larger ones.

As stated before, ample food is necessary for the proper growth of fry. A simple apparatus can be employed if one is unable to feed them several times a day. (See Figure 15.)

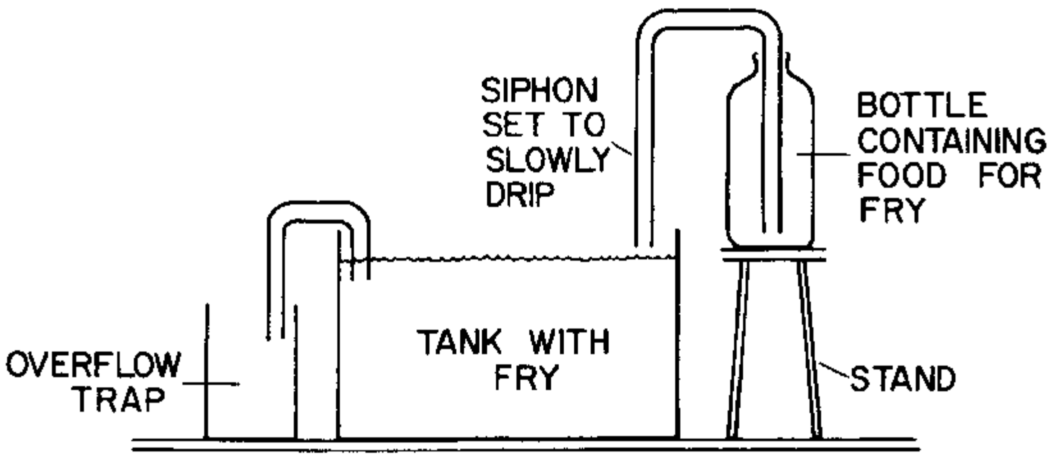

Figure 15. Apparatus for feeding fry.

E. Summary

Important points to remember when raising eggs and fry:

1. The water temperature should be held constant.
2. Change the water frequently, using water of the same quality.
3. The water should be treated with a mild fungicide.
4. Aerate the water well, but do not let the eggs contact the air or air bubbles.
5. Remove fungus-infected eggs immediately.
6. Keep eggs and fry in the shade.
7. Remove all uneaten food to prevent water fouling.

XV. NUTRITION*

A. Food Requirements

All aquatic animals and plants must eat or absorb nutrients from a water solution. Most freshwater plants accomplish this by taking up the needed phosphates and nitrates (fertilizers) by means of roots. Algae (single-celled plants or plants one cell thick) either have root-like processes to absorb these chemicals or they absorb them directly. Fishes and invertebrates capture animal food or graze on plants to obtain their nutrients. They may feed by filtering vast quantities of water through their bodies (sponges, oysters, and clams). They may snap at their food (most fishes), catch it with their claws (crabs), sting and eat it (cone shells), surround it with their bodies and absorb it through their stomachs (sea stars, flat worms), weave sticky nets to trap it (some mollusks), trap it with their tentacles (octopus, jellyfishes, corals, tubeworms), or rasp it from rocks (parrotfishes). For further information on ways that animals obtain their food, read the references listed by number at the bottom of this page.

Animals and plants convert their food into energy or building materials. With plants, sponges, and one-celled animals, food is processed within the cells themselves. With fishes and larger invertebrates, a digestive cavity performs the function of breaking down and absorbing foods into the body. Digestive cavities can be simple sacks (as in corals) or long, complicated structures (as in most fishes).

Studies on the foods of cultured fishes indicate that whether they be mullet, koi, or trout, they need at least 50% protein in their diet and they cannot utilize much carbohydrate (10%), sugar (5%), or fat (5%). This principle has been applied to most of the pellets and flake foods on the market. There is no evidence that roughage is important to fish digestion. It is important to feed fishes and invertebrates a diet which is varied and similar to their natural foods. For example, plant-eating fishes should be given spinach or limu (seaweed); meat eaters, shrimp or beef heart. Some groups of fishes will eat almost anything. However, eating a given food does not always mean that a fish can digest it. Signs of hungry or starving fishes are as follows:

1. Bites in the fins of other fishes in the aquarium
2. Bloated fishes with stringy feces
3. Fishes with concave bellies

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*For further information consult references 4, 6, 12, 17, 41, 44, 47, and 49.

New fishes may not eat for one or two weeks. If fishes which eat well are placed in the tank, the new animals may eat sooner; however, remember that new fishes may carry disease. In general, for optimal growth, fishes should be fed at about 3% of their body weight per day. Since removing fishes from the aquarium and weighing them are difficult for both fishes and aquarium owners, most aquarists suggest that fishes be given all they can eat in five minutes. If too much food is added, it should be siphoned out. Feed your fishes at least twice daily and your invertebrates twice a week. Place the food in contact with the invertebrates. It is important to watch your animals to see how much they will eat; from this you can determine how much to feed them. Many fishes will not eat unless food is presented in a way which they normally obtain it in nature. For example, coral-feeding fishes can often be induced to feed by pressing food into the skeleton of dead corals. Floating food on the surface of the aquarium is not as good as stirring it into the water.

B. Commercial and Live Fish Foods

1. Flake foods often provide a basic diet for many fishes. These may also be ground up and fed to young fishes. Standard flake foods, skim milk, high-protein wheat cereal, bran, cottonseed, or soybean meals may be used. Use these foods only half the time.

2. Pablum or high-protein baby cereals can be mixed with water, dry limu, creamed spinach (baby food is best), or chopped shrimp, and made into patties. These patties can be frozen or mixed with agar, made into firm cakes, and refrigerated.

3. Plaster of paris, cereal, and spinach can be mixed together. Dry this in blocks and place in the aquarium for parrotfishes.

4. Seaweed and freshwater plants can often be used as food. Fresh seaweed should be dipped in potassium permanganate or copper sulphate and thoroughly washed in fresh water before use.

5. Live fishes, worms, crabs, and shrimp can be raised and fed to fishes. Make sure these foods are not diseased before feeding them to the animals in your tank. Eggs and young of fishes you are raising serve as a good source of live fish food. When feeding smaller fishes to larger ones, feed the small fishes first. This gives your larger fishes the benefit of also eating the food in the stomachs of the small fishes. Vitamins can be injected into these food fish before feeding.

6. Good-quality raw shrimp and fish should be cleaned, chopped, washed, and frozen until needed. They should be thawed thoroughly before feeding. Frozen brine shrimp may carry disease organisms and should be treated with ozone or chemicals before use.

7. Raw beef heart chopped into small pieces is the best meat available to carnivores, since it contains very little fat. It can be frozen and should be defrosted and washed before being fed to fishes.

8. Chopped, hardboiled egg yolk may be fed to small fishes.

9. Freeze-dried foods such as brine shrimp should be fed occasionally. Soak these in water first.* Trout chow and koi pellets are also good food additives.

10. A few drops of ABDEC liquid vitamins and minerals may be added to the food every few days. Fishes can suffer from vitamin and mineral deficiencies. Do not freeze vitamins.

11. Parsley, carrots, and paprika can be finely chopped and mashed to provide the carotene necessary for the bright yellow and orange color of some fishes. Carotene beads may be obtained from the biological supply houses.

C. Cultured Live Foods

1. Tubifex Worms

Tubifex worms are raised or maintained in two shallow pans, one inside the other. (A layer of mud should be placed in the first pan.) Fresh water should overflow from the first pan into the second pan. Remove the worms that crawl into the second pan, wash them, and feed them to the fishes. Tubifex should be fed old lettuce leaves, leftover baked potatoes, or bread. These should be pressed into the mud. Tubifex die quickly in salt water and should be given in small quantities.

2. White Worms and Microworms

White worms and microworms are cultured in the following manner: Add enough water to pablum to make a thick paste, add a teaspoon of yeast and mix it into the paste. If the medium is too liquid the worms do not reproduce well; if it is too dry they will not crawl up the sides of the container. Spread 1/2" of paste on the bottom of a 3" high pan. Put a lid with many air holes on the pan. Start the culture with 1/2 teaspoon of white worms or microworms. When the worms crawl up the sides of the pan, they can be scraped off and fed to your fishes. When the paste turns grey and its odor is foul start a new batch. It is generally a good practice to have at least two cultures going at once.

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*Dr. J.R. Geraci, a noted researcher in fish nutrition, stated in a recent meeting that food thawed in fresh water loses much of its nutritive value. Although many people still soak or thaw fish foods in water, we have recently adopted the practice of rinsing them lightly after thawing or of adding freeze-dried foods to the aquarium.

3. Daphnia and Copepods

Daphnia and copepods are raised in freshwater containers. Add hard-boiled egg yolk, old lettuce leaves, or uncooked vegetable leftovers to create an algae-rich solution. If the container is illuminated put shelter items in the container. Add food every 4 to 5 days.

4. Infusoria (Protozoa, Rotifers)

a. Freshwater. Add yeast, algae, wheat, barley grains, split peas, or hardboiled egg to the water. Collect some pond water and let the animals grow. Collect the animals in a cloth net, rinse, and feed to the young fishes.

b. Saltwater. Add seaweed or algae and fertilizer. Plankton can be collected and frozen. At night shine a light into the water and collect these small animals with a fine mesh net. Some forms of plankton tend to swarm during the day. These may also be collected.

5. Brine Shrimp

Brine shrimp may be raised in the following manner: Fill a pint jar with salt water. Add a teaspoon of uniodized salt to bring the specific gravity of the water up to 1.040. Place shrimp eggs and brine into a shallow pan. Collect the baby shrimp with a light (to which they are attracted) at one corner of the pan. To raise adult shrimp add yeast or marine algae to the seawater and add young shrimp. If you buy adult brine shrimp, place them in the refrigerator or in brine water and aerate. Dip out the desired quantity, wash in tap water, and feed to your fishes.

6. Rubble

Rubble may be a good source of algae and small crabs but be careful: there may be larger predators such as the mantis shrimp inside.

7. Algae

a. Freshwater. Put 25 g of garden loam soil in a 50-ml flask and add 25 ml water. Plug the flask with cotton and steam for 1 hour on 3 successive days to sterilize it. Buy an algal strain from a biological supply house and add, or add pond water.

b. Saltwater. Your culture medium should contain phosphates and nitrates; several plant fertilizers such as Vigaro will do. Put a little fertilizer in a container with salt water. Single algal cultures may be obtained from biological catalogues. You can get seawater medium and flagellate algae from biological supply houses or from pet shops. Grow the algae under a fluorescent light for 14 days with aeration.

D. Natural Feeding Habits of Marine Fishes

Most tropical fish books discuss the feeding habits of fishes. The natural foods of many of our Pacific fishes have been discussed in an article "Ecological relationships of the fish fauna on coral reefs of the Marshall Islands" by R.W. Hiatt and D.W. Strasburg. The article appeared in *Ecological Monographs* in 1960.

A number of tropical fishes are listed below, grouped according to their feeding habits.

1. Herbivores

Mullets, surgeonfishes, damselfishes (in part), blennies (in part), triggerfishes (in part), puffers (in part), butterflyfishes (in part).

2. Coral Feeders

Butterflyfishes (in part), parrotfishes (in part), triggerfishes (in part).

3. Carnivores Mainly Eating Small Invertebrates

Morays, flatfishes, squirrelfishes (in part), pipefishes and sea horses, cardinalfishes, groupers (in part) snappers (in part), goatfishes, hawkfishes, butterflyfishes (in part), damselfishes (in part), wrasses, gobies, blennies (in part), triggerfishes (in part), puffers (in part).

4. Carnivores Eating Small Fishes and Larger Invertebrates

Lizardfishes, squirrelfishes, trumpetfishes, jacks, bigeyes, groupers (in part), hawkfishes, butterflyfishes (in part), triggerfishes (in part), puffers (in part).

E. Feeding Invertebrates

Most corals, crabs, lobsters, shrimps, sea stars, and brittle stars can be fed small pieces of fish or shrimp. Sea urchins and sea cucumbers and many mollusks feed on algae (seaweed). Cone shells and basket shells can be fed pieces of fish or clam. Sponges, clams, and oysters are filter feeders and may be fed dry food, baby brine shrimp, pablum, or ground up fresh material. Contrary to popular belief all sea anemones do not eat fishes. Also, many anemones die from having large pieces of food pressed to them. They will regurgitate these items and starve. Feed these animals baby brine shrimp or other equally sized organisms.

XVI. DISEASES OF FISHES AND INVERTEBRATES*

A. General Discussion

Diseases of fishes and invertebrates are caused by many factors. Disease organisms (pathogens) such as viruses, bacteria, fungi, protozoans, metazoans (commonly called "worms"), and crustacea are largely responsible for fish mortality. Many other factors such as dietary deficiencies, wounds, poisons, temperature, and changes in water chemistry are also responsible for death of fishes. Diagnoses and treatments of fish diseases have reached the highest levels of sophistication in the culture of temperate, freshwater food fishes. By contrast, information regarding diseases of tropical marine fishes and invertebrates is very limited; we know only a bit more about the freshwater organisms maintained by the hobbyist.

When a captive fish is unable to cope with a pathogen by its own internal defense mechanisms, the infective agent must be treated with drugs or chemicals.

The methodology applied to fish and invertebrate diseases is not unlike other forms of medicine. The symptoms** must be documented, the pathogen isolated and studied, the animal treated, and preventative measures discovered. This often involves working with large numbers of animals under varying conditions, and is why most work has been done on those organisms having the greatest commercial value. Thus, methods developed to treat animals in hatcheries, in public aquaria, and in various laboratories currently form the basis of what we know about diseases in tropical marine and freshwater populations.

Like man, fishes and invertebrates are subject to many diseases resulting from dietary deficiencies or improper sanitation. Prevention of disease spread may be attempted or accomplished by sterilizing containers with chlorine; siphoning out uneaten foods; regulating temperature, hardness, pH and water flow; using pathogen-free food; adding the proper dietary requirements to the food; quarantining and treating new organisms; and isolating abnormal animals. Immunological procedures may some day be helpful. Often survivors of biotic infestations lose their parasites, and in the future antibodies developed from these individuals might be beneficial in treating more susceptible members of the species.

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*For further information consult references 1, 8, 9, 14, 26, 34, 41, 42, and 49.

**Note: Strictly speaking, "symptoms" usually refers to what is subjectively felt and complained of. Again, strictly speaking, the correct word would be "signs". This refers to what is objectively seen or identifiable through physical examination, laboratory testing, etc.

Nutrition of aquatic organisms is in its beginning stages, but our knowledge of inexpensive dietary additives will probably be hastened by examination of recent papers dealing with the food of fishes and invertebrates in the natural environment and of formulas for feeding hatchery-reared animals.

A number of diseases of animals and plants have been studied. Among these, the least is known about the diseases of invertebrates. The emphasis has been placed on diseases of hatchery-reared fishes and, as a result, a number of chemicals have been developed which control diseases of tropical species with varying success. Bacterial and ectoparasitic diseases seem to be easiest to cure. In recent years, several protozoan and fungal pathogens have been controlled. However, side effects due to overdosage or prolonged treatment with specific drugs often appear from a week to two years after treatment. Some of the side effects produced are renal diseases, and lack of protein synthesis leading to nervous disorders.

Table I is a list which is not confined to tropical fishes, nor is it complete. It serves as a rough guide to determine possible causes of a disease, so that treatment can ensue.

TABLE 1. PRINCIPAL INFECTIOUS DISEASES OF TROPICAL FISHES AND THEIR MAIN SYMPTOMS

Pathogens (disease-causing organisms)	Visible Symptoms
Viruses	
Lymphocystis (fw,sw)*	Large compound white knots on skin and fins, especially on pectoral axil.
Bacteria	
Eubacteriales (gram-negative)	
Aeromonas (fw,sw) (ascites)	Swollen body, ulcers (open wounds), white or red patchy discoloration, fin rot, red discoloration of the anus, eyes sunken.
Pseudomonas (fw,sw) (dermatitis)	Ulcers, fin rot.
Vibrio (sw)	Red patchy discoloration, fin rot, ulcers, eye discoloration, body degeneration, scale loss.
Haemophilus (fw)	White spots quickly developing into round ulcers; inflamed jaws and palate; ulcers to bone; fin rot.
Actinomycetales (acid-fast)	
Mycobacterium (fw,sw) (fish tuberculosis)	Pallor, milky or red spots on skin, ulcers, popeye, fin degeneration, loss of weight, jerky movements.
Myxobacteriales (gram-negative)	
Cytophaga (fw,sw) (columnaris disease)	Grey or white spots, shallow ulcers, fins frayed, gill filaments swollen or fused.
Fungi	
Ichthyosporidium (fw,sw)	Loss of equilibrium, ulcers.
Ichthyophonus (fw,sw)	Mouth partly open, loss of fins, black discoloration.
Saphrolignia (fw)	Deposits on skin that look like cotton wool.

Protozoa	
Flagellata	
Costia (fw) (slimy skin disease) internal flagellates (fw)	Pallor on skin and gills, skin shedding, weight loss, listlessness.
Dinoflagellata	
Oodinium (fw,sw) (velvet or rust disease)	Numerous tiny spots on fins, body and gills.
Sporozoa	
coccidians, myxosporidians (fw,sw) (internal - usually found in wild fish)	Abdominal swelling, reddening of anal pore.
microsporidians (usually found in wild fish)	
Glugea (fw)	Round, pea-sized white cysts.
Plistophora (fw,sw) (neon fish disease)	Swelling, paralysis, fin degeneration.
haplosporidians (fw)	Cylindrical, large, white cysts.
Cilliata	
Ichthyophthirius (fw) (Ich or white spot disease)	White granules on skin and fins; tail rot; stiffness of pectoral fins.
Cryptocarion (sw) (Ich)	As above for marine fishes (Ichthyophthirius).
Metazoa (commonly called "worms")	
trematodes (fw,sw) (flukes)	Often a bluish white membrane on skin and gills. (Flukes live in gut, blood, eyes, liver.)
tapeworms	Belly becomes swollen.
leeches (fw,sw)	Visible on body.
Crustacea	
copepods (fw,sw) (anchor worms)	Either parasites are visible or there are round, red or white, walled defects or swelling on skin, fins and gills.
Isopods (fw,sw) (tongue worms)	Visible in mouth and gills.

*fw = freshwater organism. sw = saltwater organism.

B. Isolation and Treatment of New Fishes

Newly acquired fishes which do not show any disease symptoms often carry pathogens capable of infecting other fishes. Before adding fishes to an established aquarium, most aquarists use prophylactic procedures (preventative medicine) or isolation techniques on the new animals. A variety of techniques are used. The more common of these are described here.

A small all-glass aquarium with a filter containing only dacron wool should be set aside as a "hospital" tank. The new fishes are placed in this tank for two weeks of observation. If there are no signs of disease, they may be introduced into an established aquarium.

Freshwater fishes often carry fungal and protozoan parasites and may be treated for one week in the "hospital" tank with weak concentrations of noniodized salt (1 teaspoon per gallon), malachite green, or methylene blue B (follow the directions on the bottle).*

Saltwater fishes often carry ectoparasites and flagellate pathogens. One standard treatment is to maintain the fishes in a 0.15 ppm concentration of $CuSO_4$ for one week. In addition to $CuSO_4$, the fishes are given a formalin bath (1 cc per 5 gallons) three times during the week. The formalin is added to the hospital tank, and the fishes are left in it for 1 hour. The whole tank is then flushed and new $CuSO_4$ is added. When adding formalin, dilute it in a glass of water and then add it to the aquarium. A stock solution of $CuSO_4$ can be made to fit the 0.15 ppm concentration requirement.* Fishes have individual tolerances to these chemicals, so one should be careful when using them. If a fish appears to be distressed, change the water.

In addition to the copper sulfate treatment another prophylactic technique may be employed. There is some indication that a few marine pathogens cannot tolerate a change from the normal salinity of seawater. However, many fishes adapt quite readily to a slightly lower salinity. Some aquarists have used this difference in ability to tolerate salinities as a preventative measure against disease. After the normal isolation period in the hospital tank, the fishes are slowly acclimated to a lower salinity of 1.020 instead of the normal salinity of 1.025. Fishes kept in this manner have survived well without any apparent effects due to the less saline water. It should be added that there is only a functional correlation between lower salinity and health of the fish. It still remains to be tested whether lower salinity truly affects the free-living pathogens.

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*See Table 2 for a list of specific pathogens, suggested medicines, and instruction for preparing solutions.

C. Treating Fish Diseases

We have not yet tested all of the treatments listed in Table 2, but they have been reported as effective if used carefully. Some fishes may not be able to withstand the medication. Watch for signs of distress, remove the fishes, and use an alternative treatment. You may ask a doctor or veterinarian to procure these drugs and chemicals for you, or you can examine the fish medicines on the market, to determine whether they contain any of the ingredients listed. All chemicals should be pre-dissolved before they are added to bath or dip water.

A diatom filter is exceptionally good for removing dead disease organisms and cysts from a tank. Keep one in operation after treatment for 3 or 4 days.

There are three basic ways of administering a drug: in a bath, in a dip, or mixed with food.

1. Baths

A bare, all-glass 5- to 10-gallon aquarium should be used as a bath. Fill the aquarium with water from the original tank and add the infected fishes or invertebrates. Add the pre-dissolved chemicals slowly to the bath until the required dosage is established. Leave the animals in the bath for the prescribed number of days; meanwhile, add a disinfectant to the original aquarium and filter. Wash the aquarium with running water and add new seawater or aged fresh water. Adjust the temperature of the tank to that of the bath and replace the treated animals.

2. Dips

Remove the organisms from the tank in a net. Leave them in the net and place them in the dip, or pour the desired concentration of chemical over the animal. Dips may help prevent disease in newly acquired organisms, but are not recommended for diseases which occur in established aquaria.

3. Food

Add fresh chemicals in the desired concentrations to the food, mix well, and immediately add to the tank. Unless specified, all dosages listed below call for 100% activity of the chemical. When you obtain the drug, read the label and if the amount of active compound in the drug is only 50%, add twice as much. Most chemicals when added to food require that you know the weight of the fishes to be treated. To do this, place the animals in a container with water and weigh the container and water. By subtraction you will obtain the weight of the fishes.

TABLE 2. TREATMENTS FOR FISH DISEASES

Disease Categories and Medications	Dosages and Comments
Bacterial Diseases	
Gram-negative bacteria	
Furanase (Abbott Laboratories)	Bath: 4 - 12 mg/gal water for 6 days.
Polycillin* (Ampicillin trihydrate)	Bath: 250 mg/gal water for 6 days.
Aureomycin* (Chlorotetracycline)	Bath: 50 mg/gal water for 6 days.
Chloromycetin* (Chloramphenicol, Amphicol-V)	Food: 2 - 5 mg/100 g fish for 14 days. Bath: 250 mg/gal water for 6 days.
Erythromycin* (Maracin)	Food: 10 mg/100 g fish for 21 days. Bath: 250 mg/gal water for 6 days.
Terramycin* (Oxytetracycline)	Food: 5 - 10 mg/100 g fish for 11 days.
Acid-fast and gram-positive bacteria	
Isonicotinic acid hydrozide	
Icanamycin	(These might work, but we know of no tests on fishes.)
Garamycin	
Fungal Diseases	
Acriflavine (for eggs and larvae only)	Bath: 40 mg/gal water until larvae are about 2 weeks old.
Malachite green (zinc free)	Bath: Use 1% stock solution - add 1 drop/gal water for 3 days then 1 drop/2 gal for 4 days. Dip: 228 mg/gal water for 30 seconds.
Potassium permanganate	Bath: Use 37% solution - 38 ml/gal water for 30 minutes.
Sulfathiozole sodium	Bath: 1 level teaspoon/gal water for 14 - 20 days.
Salt	Bath: Add 5 doses, each 1 level teaspoon/gal water at intervals of a few hours.

Amphotericin B*†	Bath: 1 part/10 million parts water for 7 days.
Griseofulvin†	Bath: 250 mg/20 gal water for 7 days.
Ectoparasites	
Formalin (Formaldehyde 37%)	Bath: 37% solution - 1 ml/gal water for 1 hour; repeat 3 times at intervals of 3 - 4 days.
Malachite green	(See Fungal Diseases.)
Mercurochrome	Crush the parasite or pull it out and apply medicine to wound directly.
Potassium permanganate	(See Fungal Diseases.)
Protozoan Diseases	
Oodinium and other flagellates	
Copper sulphate	Bath: Use stock solution 2.23 g hydrated copper sulphate and 1.5 g citric acid in 1 liter water - add 1 ml/gal water for 2 weeks.
Skin parasites	
Atabrine	Bath: 38 mg/gal water for 7 days.
Formalin	(See Ectoparasites.)
Ich and other cilliates	
Methylene blue B	Bath: Use 5% stock solution; add 15 drops/gal of salt water for 5 days or 15 drops/gal of fresh water for 2 weeks.
Potassium permanganate	(See Fungal Diseases.)
Cilliates and Sporozoa	
Sulphanilamide	Bath: 380 mg/gal water for 7 days.
General	
Quinine hydrochloride or sulphate	Bath: Add 3 doses, each 38 mg/gal water at 12-hour intervals; leave for 20 days.
Salt	(See Fungal Diseases.)

Flagyl†	Bath: 250 mg/20 gal water for 7 days.
Malachite green	(See Fungal Diseases.)
Intestinal "Worms" (metazoans)	
Di-n-butyl stannous oxide	Food: 1.5 mg/.10 g fish for 3 days.
Hydrogen peroxide	Bath: 35% solution - 0.3 mg/gal water for 5 hours.
Methylene blue B	(See Protozoan Diseases.)
Quinine hydrochloride	(See Protozoan Diseases.)
Miscellaneous Diseases	
Constipation	
Glycerine	Food: A small quantity mixed with dry food until condition clears.
Eye problems	
Neoprontosil	Coat eye and place fish in the dark.

*Will often cause side effects, and remains active for one year.

†Currently being tested.

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XVIII. APPENDICES

APPENDIX 1

Sample Form for Collecting and Maintaining Marine Aquatic Animals

Family________________________ Genus, species__________________

Common name__________________

Substrate preference[1]______________________________________

Depths found____________________ Vertical zonation[2]______________

Best method of capture_____________________________________

Decompression time____

Food preferences - Aquarium_______________, Field_______________

Compatibility - Same species_______________, Other species_________

Cover preference in aquarium_______________________________

General behavior____

Diseases____

Comments____

[1]Substrate preference: sand, rubble, limestone or basalt, live coral, algal mats

[2]Vertical zonation: tidepool, splash zone, surge zone, back-reef, reef slope, reef flat

APPENDIX 2

Weights and Measures

Home measures are rough, but they at least provide the aquarist with an approximate measure when adding a food or chemical to an aquarium. A postal scale is handy for weighing, and a mortar and pestle for grinding. Use standard measuring cups and spoons.

Fluid (water)

Home Measure	Metric
1 drop from eyedropper	1/20 cc (or ml)
1 teaspoon	5 cc
1 tablespoon	20 cc
1 cup	300 cc

Solid (salt)

Home Measure	Metric
1 level teaspoon	5 grams
1 level tablespoon	20 grams
1 level cup	370 grams

When working with percentages or parts per million (ppm), 1 cc water weighs 1 gram. Thus a 1% salt solution is 1 gram of salt to 100 cc water. To make a gallon of this (1 gallon = 3-1/2 liters or 3500 cc) we need 35 grams of salt, or 1 tablespoon + 3 teaspoons of salt.

Reference: Emmens, C.W. 1971. *How to Keep and Breed Saltwater Fish.* Neptune City: T.F.H. Publications.

APPENDIX 3

Underwater and aquarium photography is a course in itself. If you wish to learn more either take the Aquatic Photography course offered by Dr. A. Reed in the Continuing Education Department, University of Hawaii, or read the following suggested booklets.

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Church, J., and Church, C. 1972. *Beginning Underwater Photography*. 2nd ed. J. & C. Church, P.O. Box 80, Gilroy, California 95020.

Eastman Kodak Co. Basic Scientific Photography. *Kodak Scientific Data Book*, N-9. Rochester.

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