Water Gardens

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Water gardens or garden pools have become a popular part of landscape architecture in the United States. Water gardens are visually soothing and seem to connect people to the natural aquatic world. The esthetic value of water gardens is enhanced by the almost endless variety of design and planting options that make each one a unique and personal creation.

Little formal research has been conducted on the ecology and management of water gardens, so most of the information in this publication was developed from related areas of research and practical observations.

Water garden location, size and type

The location of the water garden is critical to its ecology and maintenance, as well as to your enjoyment of it. Sunlight is needed for plant photosynthesis. Plants are important to the water garden's ecology because they produce oxygen, remove and recycle nutrients, and provide shade and hiding places for fish and other inhabitants. A water garden should be situated to receive at least 6 hours of sunlight each day. However, direct sun at mid-day during the warmest months can cause shallow pools to overheat. Locating the water garden so that it can be viewed from the house will increase your enjoyment and allow you to supervise it. Be sure to control access to the water garden to ensure the safety of children. A good view of the water garden will also help you spot unwanted visitors such as predators.

Water gardens should not be located over utility services. Check with utility companies for the location of underground lines. Water gardens should not be located directly under trees because roots hamper excavation and may cause structural damage later. Also, leaves foul the water and over-hanging branches may exude toxic substances into the water garden. Consider the weight of the water before placing a free-standing water garden on a patio or deck. Check structural supports; water is very heavy.

The depth of a water garden depends on design, local climate, and over-wintering strategies. Many year-round outdoor water gardens have a section at least 3 or 4 feet deep that does not freeze in the winter and gives fish a cool retreat during hot weather. Large koi carp, in particular, tend to lose color and become stressed if they do not have a cool place to stay during hot weather. A depth of 18 to 24 inches is sufficient in the deep south, as long as only a few fish are stocked and plenty of floating aquatic plants are provided for shade. Water gardens that are at least two-thirds below ground level retain heat in cold weather and are cooler in hot weather. Those built totally above ground may have to be drained during the winter and fish and plants moved indoors. Ponds can be built of several types of materials. Some of the more common are earth, plastic liners, fiberglass and concrete (Table 1). Plastic liners are easy to install and come in a variety of shape and sizes. The lifetime of a liner depends on the thickness and type of plastic.

Construction

Construction of a water garden can be simple or complex. Water gardens built of fiberglass or concrete take considerable construction skill. Earthen and plasticliner pools require less construction skill or experience. Many commercial firms selling water garden equipment offer consulting services on design, construction and maintenance. Use available expertise and your own creativity to design a water garden reflecting your imagination and taste.

Water gardens can be relatively expensive to build and maintain. Cost of construction varies with size and the materials used, but can range from a few hundred dollars to many thousands of dollars. Construction plans should be reviewed by local governmental agencies (e.g., Building and Zoning) to ensure that the proposed pool complies with all building codes. For example, all electrical service should have ground-fault interrupt circuits. Permits may be required. Water gardens deeper than 18 inches may be considered an "attractive nuisance" by insurance companies and may need to be within a fenced area. Check with your insurance company before construction. Water gardens may be irregular or geometric in shape. Irregularly shaped water gardens have a natural look, while the geometric shapes appear more formal. Before you start construction, try laying out possible water garden designs using a garden hose or rope.

Before construction, plan where pipes, filters, water pumps, etc. will be located and how they will be concealed. Plan where electrical and water lines should be placed for night lighting, pumps, fountains or waterfalls, and set foundations for such structures as stepping stones, a walking bridge, or the base of a fountain. Plan how the water garden will be drained. Make sure the bottom slopes so the water will drain to a point where it can be siphoned or pumped. Constructing a catch basin (usually 6 to 12 inches deep) in the deepest part of the water garden will concentrate fish during drainings and make it easy to capture them.

Rainwater run-off can cause problems in excavated water gardens, so make sure that run-off water does not flow into

Table 1. Typical construction materials for water gardens.

Pool type	*Advantages*	*Disadvantages*	*Special considerations*
earthen	inexpensive, especially for larger pools	seepage, wild plants may become established	soil must have a high clay content
flexible liners	ease of construction	possible punctures, must be pumped or siphoned to drain	type of liner will determine lifetime, usually 10 to 20 years
fiberglass/plastic	durable, long life	shallow, not the best habitat for large fish, good for plants only	very small pools could be moved inside during the winter, can crack if water freezes
concrete	very long life, can be constructed with decorative tiles	expensive, can crack and leak, must be cured	may need to be coated with epoxy or pool paint to stop leaching of minerals

the water garden. Run-off water can allow fish to escape, introduce chemical contaminants, cause muddiness, and may cause oxygen problems. If the surrounding terrain is higher than the water garden, a berm may be required to direct run-off water away from the garden. Another problem can be rainwater saturation of the soil under the water garden, which can cause it to overflow or float out of the ground. To avoid this problem, construct special drainage systems under the pool.

Vertical sides let detritus (dirt, leaves, etc.) build up along the edge of the pool bottom, so sides should be tiered and/or sloped to move detritus toward the deepest part of the pool where it can be cleaned out. A common construction method is to cut pool sides into two or three tiers, each about 12 inches wide. Tiers help to hold liners in place and provide ledges for plants and other decorative items.

To protect a liner from being punctured by roots and rocks, firmly compact the dirt along the pool sides and bottom and covered it with sand and/or old carpeting before installing the liner. Borders of flagstone, brick, or wood decks overhanging the water by 1 to 2 inches help conceal liner edges and hide pipes, wires and equipment. The water garden's interior may be decorated with sand, gravel or rocks.

Much of the enjoyment of owning a water garden is in designing and landscaping the pool and the surrounding area. Consider using rocks of varying colors and shapes, fountains, waterfalls, windmills, underwater lighting, islands, bridges, and surrounding flower gardens.

Some designers landscape around water gardens with arches, gates, fences, and even gazebos to enhance their beauty

Remember to level your pool accurately! Otherwise, the water garden may end up with an exposed area at one end and water about to overflow at the other end.

Water

Quality

Whether your water garden is a plastic tub or an aesthetic wonder, good water quality is essential. Poor quality water makes the water garden less attractive and can harm fish and plants. Once the basics of water quality are understood, maintenance will require a minimum of time.

The first consideration is a supply of good quality water to fill the pool. The most common sources are city water and well water. Surface water from a creek or pond is not recommended as it may contain contaminants, diseases and wild fish, any of which may harm the water garden's ecosystem. If city water is used it must be dechlorinated before adding fish and plants. One week of sunlight (or less, if aerated) will dechlorinate city water if the chlorine source is liquid or gaseous chlorine. If the chlorine source is chloramine, it is best removed by chemical dechlorination. Commercial dechlorinators made from sodium thiosulfate are available in liquid or pelleted forms from aquarium and water garden retailers.

Water quality factors to consider are dissolved oxygen, ammonia, nitrite, pH, alkalinity, hardness, carbon dioxide, and contaminants or pollutants (such as pesticides). These factors have different levels of importance to water gardens. For additional information on water quality see SRAC Publication 452.

The amount of oxygen that dissolves in water (D.O.) is very small and is measured in parts per million (ppm or mg/L). The amount of dissolved oxygen in a water garden can range from 0 ppm to more than 20 ppm. Oxygen dissolves directly into the water garden from the air if the water is agitated by wind, waterfalls, etc. Underwater plants also produce oxygen as a byproduct of photosynthesis. The amount of oxygen in the water will vary with the amount of agitation, the numbers of fish and plants, the time of day, and the water temperature. More oxygen can dissolve in cool water than in warm. As temperature increases in the summer, fish increase their metabolism, less oxygen can dissolve in the water, and respiration from decomposition is highest. All of this can lead to low dissolved oxygen, particularly at night when underwater plants are also using oxygen in respiration. Fish will become severely stressed at D.O. concentrations below 3 ppm and will die at a D.O. concentration of about 1 ppm. Mechanical aeration from waterfalls or fountains can maintain minimum D.O. concentrations (and remove excess carbon dioxide).

Water garden nutrients come from fish feed, wastes, decomposing leaves and other types of organic matter, and from fertilizers applied to pool plants. In a well balanced water

Water garden in a barrel.

Leveling the pond during construction.

A formal watergarden, fountain and waterlillies

Algae growth clinging to aquatic plants.

A less formal water garden with natural materials and an irregular shape.

garden, plants will remove nutrients rapidly and suppress algal growth. If there are excessive nutrients algal growth is stimulated. Pool algae can be filamentous (stringy or hair-like) or planktonic (green water). Both types quickly become a nuisance by clinging to plants, decorations, etc., clouding the water, and restricting the view of fish and plants. Dense algal growths can deplete oxygen at night or during extended cloudy weather.

Periodic algal blooms are part of the natural cycle, particularly from fall to early spring when ornamental plants are not actively absorbing nutrients. Cleaning debris from the pool will help during these periods. If warm weather algal blooms occur, then over-stocking and over-feeding fish or over-fertilizing pool plants is usually the problem. Solutions include increasing the number of pool plants, adding bio-filters to remove excess nutrients, or flushing water through the pool to dilute nutrients and disperse algae.

Ammonia is the major nitrogen waste excreted by fish. Bacteria decompose ammonia to nitrite. Ammonia and nitrite are both toxic to fish but are seldom problems in water gardens. These compounds are normally removed from the water by pool plants that use them as nutrients. Ammonia and nitrite can become problems if fish are over-fed, plants are over-fertilized, or organic matter in the garden (e.g., leaves, dead plants, fish, etc.) decomposes rapidly. Excess ammonia and nitrite can be removed by biofiltration (see Filtration section), by flushing, or by adding bacterial water conditioners.

The pH of water is measured on a scale from 0 to 14, with 7 being neutral (<7=acidic, >7=basic). Water garden pH changes daily because of plant photosynthesis and respiration of plants and other organisms. Fluctuation from 6.5 to 9 will not harm the water garden's ecology. A pH much above or below this range will stress or even kill fish. If the pH is shifting above or below this range, you will need to increase the water's alkalinity to buffer these fluctuations. Alkalinity can be increased by adding carbonates such as agricultural limestone, oyster shell, or bicarbonate of soda. An alkalinity of more than 20 ppm is considered adequate, but 50 ppm or more is better (see SRAC Publication 464). Water quality tests for D.O., ammonia, pH, alkalinity, and chlorine can be purchased at most water garden or aquarium suppliers. It is a good idea to have testing equipment available should problems arise.

Filtration

The water volume of the garden must be determined before you select a filter or pump, or perform any chemical treatment. For information on calculating area and volume of pools, see SRAC Publication 103.

Not all water gardens need filtration.
Water gardens with lots of plants and a modest number fish should not need filtration. If a balance is maintained between the number of plants, the number of fish, and the amount of nutrients the water garden receives, then no other filtration should be necessary. However, keeping the proper balance is as much an art as a science. For this reason, many people become frustrated and opt for additional filtration.

There are two types of filters—mechanical and biological. Mechanical filters remove or trap particles of dirt and organic matter. Leaf skimmers, foam filters, and settling basins are the most commonly used mechanical filters in water gardens. Sand filters and cartridge filters like those used in swimming pools or hot tubs are not recommended for water gardens because they clog quickly and are difficult to keep clean.

Biological filters remove excess nutrients from fish wastes, fertilizers and decomposing organic matter. Bacterial bio-filters are popular for water gardens, particularly those in which fish are the major attraction. Bacterial bio-filters contain layers of gravel or coarse sand, plastic sheets or rings, mesh or foam, or some other material as a substrate on which bacteria grow. Bio-filters operate best in a pH of 7 to 8 and an alkalinity of >50 ppm. Adjustments of pH and alkalinity can make bio-filters more efficient. Bio-filters require little maintenance if properly designed.

Under-gravel filters, common in aquariums, are one of the simplest types of bio-filters. The gravel acts as a mechanical filter and is colonized by bacteria. Large gravel filters can be built into the water garden bottom or constructed as a stream bed outside the garden. Water is pumped from the pool over the gravel bed and back to the pool. The problem with gravel filters is that they become clogged with solids and require laborious cleaning.

A common type of in-pond filter uses plastic media and foam surrounding or connected to a submersible pump. It acts as both a m chanical and a biological filter (Fig. 1). The pump draws water through the filter media, trapping sediment and providing an area for bacteria to grow. With this type of filter, sediment must be removed periodically and the foam cleaned frequently. Other bio-filter designs can be found in aquaculture and water garden publications.

Fish

Stocking rate

One common mistake is stocking too many fish. A water garden is suitable for fish only as long as it can supply adequate oxygen and decompose the wastes produced. The number of fish the water garden can support depends on factors such as the size of the water garden, size of the fish, temperature, amount of sunlight the water garden receives, whether or not aeration is provided, and how well the natural or artificial filtration system removes wastes. The following examples give stocking rates recommended by fish hobbyist magazines.

First, determine the water garden's surface area in square feet. An unaerated water garden can be stocked at up to one 12-inch fish (not including the tail) per 4.5 square feet of surface area. If the water garden is aerated with fountains or waterfalls, then stock up to one fish per 2 to 3 square feet. (Conservative water garden hobbyists suggest stocking only 6 inches of fish per 5 square feet of surface area or 8 to 12 inches of fish per 16.5 square feet of surface area.)

For example, if a water garden measures 9 feet by 15 feet, the surface area is 135 square feet. Dividing 135 square feet by 4.5 square feet (per 12 inches of fish) equals 30 units of 12 inches or 360 inches of fish total. The average adult koi carp is 18 inches long, so this 9 x 15 foot water garden can support 20 adult koi carp (360 inches ÷ 18 inches each = 20 fish). (Top exhibitors in Japan stock only 10 to 15 koi even in large water gardens.)

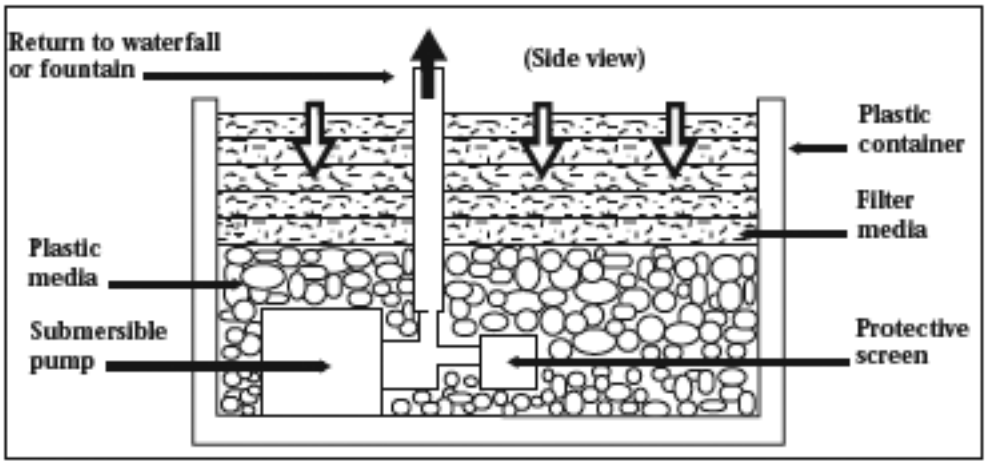

Figure 1. In-pond mechanical/bio-filter.

Types of fish

Fish most commonly stocked in water gardens belong to either the goldfish or the koi family. There are numerous varieties of these fish.

References to goldfish are found in Chinese poetry as early as 1,000 A.D. The Chinese and Japanese nobility developed many of the varieties we see today from the original wild form. Today there are many varieties to choose from. Varieties with normal body structures are best for water gardens. These would include common goldfish, shubunkin (or calico), comet, and fantail. Varieties of fancy goldfish such as the nymph, fringetail, veiltail, lionhead, curled gill, and bubble-eyed goldfish are not well suited for outdoor water gardens because they are more vulnerable to predators.

Koi carp are descendants of the European common carp (Cyprinus carpio). Koi is a Japanese word meaning "love" and koi giving in Japan has much the same meaning as flower giving in the West. Koi have been bred in Japan since at least 300 A.D. and are a popular ornamental fish because of their wide variety of colors and color patterns. Each color and pattern combination is given a distinctive Japanese name. Prized koi have bright, intense colors, sharp color definitions, and distinctive arrangements of markings. Koi with exceptional coloration and patterning can be valued at thousands of dollars. Koi can grow quite large and sometimes live for 60 or 70 years. These fish can truly be lifelong pets.

Acclimating the fish at stocking

Before purchasing fish be sure that they appear healthy (see Disease section). Fish must be stocked correctly if they are to remain healthy. It is necessary to acclimate the fish to the temperature and pH of the water garden. To do this, float the transport bag containing the fish in the water garden for 10 to 15 minutes. Keep the bag out of direct sunlight. A plastic bag acts like a magnifying glass and will rapidly heat the water inside. Next open the bag and slowly splash water from the water garden into the bag. Check the water temperature in the bag and water garden with a thermometer or your fingers. Once the water temperatures are the same or within 2 or 3o F, release the fish into the water garden. It is best to dip the fish out of the bag and not add transport water to the pool. The fish should swim and behave normally.

Feeding fish

Over-feeding fish is one of the most common problems in water gardens. Fish can be fed for either growth or maintenance. If you want fish to grow rapidly then you must either stock fewer fish or increase the water garden's filtering capacity. Once fish have reached the desired size, feeding should be reduced to a maintenance ration.

Feeding rates can be estimated by approximating fish weight based on their length (Table 2). A feeding rate of about 3 percent of total fish weight per day during warm weather (water temperature above 70 F) will promote rapid growth (Table 3). Maintenance feeding is calculated as 1 percent of fish weight, fed only 5 days per week. Remember, a maintenance diet is meant to sustain the fish and keep them healthy. Fish usually grow a little even on a maintenance diet because of the abundance of natural food organisms in a water garden.

Fish should consume feed quickly (within 5 minutes) in warm weather. Never feed more than the fish will eat within 15 minutes. If the fish do not consume all the food within 15 minutes you are over feeding or the fish are under stress and/or have a disease. Reduce the amount you feed when water temperature is high than 90 F. At high temperatures fish do not feed well and are easily stressed by poor water quality. Feeding activity alsodeclines when temperatures drop because fish metabolism decreases. Fish do not feed at water temperatures below 45 F. Uneaten feed can create water quality problems. It is a good practice to remove uneaten feed.

If fish grow too large for the pool's carrying capacity, remove some of them to prevent problems such as heavy algal blooms, diseases, and/or oxygen depletions.

Aquatic plants

Aquatic plants not only add beauty to a water garden but are also effective filters and nutrient absorbers. Plants such as sagittaria or anacharas (elodea) come in a bunch and are submerged into the garden in areas where there is water movement. These plants multiply quickly, filtering and oxygenating the water. Plants such as water lilies, reeds, lotus and primrose are submerged in their pots to the proper depth. Plants such as hyacinths float with roots free in the water to absorb nutrients.

Choose plants that will not drop debris into the water garden, because organic matter can clog filters and deplete oxygen as it decays. Many tropical aquatic plants such as hyacinths and tropical lilies won't survive winter freezes and must be brought indoors. Hardy aquatic plants such as native water lilies and water iris are winterized by cutting off old growth and placing their pots in the bottom of the water garden (below the freeze line). Check with the ornamental plant dealer as to the best care for your plants.

Plants are best potted in plastic buckets, pans or baskets. Baskets lined with burlap or similar material effectively hold soil around the plant roots but also allow plants to absorb nutrients from the water. Plants should be potted in a heavy clay soil, free of organic matter, fertilizers and pesticides. Fertilizers used in water gardens should be slow-release pellet formulations developed especially for aquatic application. Place fertilizers deep within the rootball to prevent leaching of nutrients into the water and do not overfertilize.

A good rule-of-thumb is to use floating plants or other plants that closely shade the water to cover 50 to 75 percent of the pond's surface. These plants limit sunlight reaching the water and the pool bottom, thus suppressing algal growth. Plants with floating leaves, such as water lilies, should be in a quiet, undisturbed area of the pool away from waterfalls and fountains. Submerged plants such as anacharas should be planted at one bunch per 2 to 3 square feet of pool surface. Usually 6 to 12 bunches are planted in a single pot. Little fertilization is needed for submerged plants.

Many people construct water gardens for the beauty and variety of aquatic plants and do not stock fish at all. If both are desired, then aquatic plants may need to be protected from plant-eating fish such as koi carp. Wire or plastic net enclosures work well. Feeding fish several times a day also reduces the amount of plant matter they eat.

Many plants used in water gardens are exotic or nonindigenous species, often purchased by mail order. Remember that it is illegal to possess certain nonindigenous plants in some states because of the threat they pose to the natural environment. Check with your state Game and Fish or Natural Resource agency for lists of restricted aquatic species before planting your water garden.

Problems

Algae control

If algae starts to cut down on visibility, the natural tendency is to treat with herbicides. This is not a good idea as herbicides can kill fish if not applied properly or if the dead, decaying algae depletes oxygen. Herbicides also can harm the decorative aquatic plants in the water garden. A heavy algal bloom is usually a sign that there are too many nutrients in the water. To treat the problem, you can flush with fresh water, reduce feeding or fertilization, add more aquatic plants or bacterial water conditioners, and/or reduce the number of fish in the water garden.

Some water gardeners like to add snails in an attempt to control algae. A word of caution: Many snail species reproduce rapidly and will feed on, and damage, desirable plants as they become overpopulated. Many snail species will migrate from the water garden and spread to other water sources. Some snail species are exotics and should not be allowed to escape into the natural environment. If you want snails, pick the species carefully.

Controlling fish reproduction

Another common problem in water gardens is fish reproduction. Over-population of fish will limit their growth, jeopardize their health, and degrade water quality. Many fish eggs and fry may be eaten by the larger pool fish and aquatic insects, but if only a few survive the water garden will become over-populated. One biological control method is to stock one sunfish (e.g., bluegill). Sunfish are voracious and aggressive enough to eat all fish eggs and fry in most water gardens. Most sunfish are also quite attractive and will not grow too large.

Fish diseases

Fish diseases are almost always preceded by stress, which has a wide variety of causes. Signs of stress or disease are easy to spot and watching for them should become a part of routine water garden maintenance. Common stress/disease signs are: reduced or no feeding; piping (sucking air at the surface); flashing (quickly turning sideways and rubbing on objects); whirling; shredded fins; and visible sores or discolorations. There are more than 100 known diseases and parasites that can infect most species of fish. Fish diseases can be diagnosed by a qualified fish diagnostician or veterinarian with fish disease training (see SRAC Publications 472 and 474). To make a diagnosis a fish must be alive when examined, and the fish usually must be sacrificed in the diagnostic procedure.

Predators and other nuisances

A water garden attracts wildlife, some of which may prey upon its inhabitants. Predation by birds, cats, raccoons, snakes, turtles, frogs, and other animals is a problem that cannot be eliminated entirely. Fences may reduce some predation problems. A net over the pool reduces bird predation but detracts from the water garden's beauty. Plastic owls or hawks may discourage some birds. You must decide what you are willing to tolerate and attempt to discourage the rest.

Release of plants and fish

Many of the plants and fish commonly included in water gardens are exotic or non-native species. These include the goldfish and koi, water hyacinth, water lettuce, water ferns (Salvinia's), and many other aquatic plants. Exotic species should never be allowed to escape or be released into the wild. If your pool becomes overcrowded, reduce the number of animals and plants by disposing of them properly. Fish can be euthanized by putting them in a bag filled with water and then placing the bag in a freezer for several hours. Plants should be removed from the water garden, allowed to dry-out or desiccate for several days, then composted or disposed of in a sanitary landfill. Do not create ecological problems by releasing these nonnative species!

Conclusions

A water garden is a wonderful way to enjoy the natural beauty of aquatic plants and animals and gain a better understanding of the complexities of aquatic ecosystems. Designing the water garden and its surroundings is an outlet

Table 2. Approximate length to weight relationships for carp and goldfish.

Total length (inches)	*Carp*		*Goldfish*	
	weight per 10 fish (pounds)	*individual weight (ounces/grams)*	*weight per 10 fish (pounds)*	*individual weight (ounces/grams)*
2	0.08	0.13/3.6	0.05	0.08/2.3
2.5	0.14	0.22/6.4	0.09	0.14/4.1
3	0.22	0.35/10	0.17	0.27/7.7
3.5	0.33	0.53/15	0.25	0.40/11.3
4	0.47	0.75/21.3	0.40	0.64/18.1
4.5	0.65	1.04/29.5		
5	0.85	1.36/38.6		
5.5	1.09	1.74/49.4		
6	1.37	2.19/62.1		
6.5	1.67	2.69/75.8		
7	2.06	3.29/93.4		
7.5	2.47	3.95/112.4		
8	2.93	4.69/132.9		
8.5	3.44	5.50/156.0		
9	3.99	6.38/181.0		
9.5	4.60	7.36/208.7		
10	5.27	8.43/239.1		
11	6.77	10.83/307.1		
12	8.51	13.62/386.0		
13	10.50	16.80/476.2		
14	12.76	20.42/578.8		
15	15.74	25.18/714.0		
16	19.03	30.45/863.2		
17	22.96	36.7/1042.5		
18	27.47	44.0/1246.0		
19	32.33	51.7/1466.5		
20	37.76	60.4/1712.8		

Table 3. Feeding rates, based on water temperature, for growth or maintenance rations.

Water temperature (°F)	*Growth ration (% body weight/day)*	*Maintenance ration (% body weight/day[1])*
	Fish less than 1/2 pound	
> 90	1.0	0
70 - 90	3.0	1.0
60 - 69	2.0	0.5
50 - 59	1.0	0.2
45 - 49	0.5	0
< 45	0	0
	Fish more than 1/2 pound	
> 90 1.5	0	
70 - 90	3.0	1.0
60 - 69	2.5	0.7
50 - 59	1.0	0.5
45 - 49	0.5	0.2
< 45	0	0

[1]Feed only 5 days per week.

for creative expression and enables urban dwellers to add a serene, natural environment to their yards.

There are many books and magazines available on building and maintaining water gardens. Gather as much information as you can through your library and bookstore, and visit with neighbors who have water gardens. Local garden clubs may be able to put you in contact with water garden owners and may periodically offer tours of water gardens in your area.

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