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 plastic-liner 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 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 cover 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

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**Table 1. Typical construction materials for water gardens.**

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

A formal water garden, fountain and waterlilies.

Water garden in a barrel.

Algae growth clinging to aquatic plants.

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

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 nympha, 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.
above 70°F) will promote rapid
weather (water temperature
fish weight per day during warm
ing rate of about 3 percent of total
reached the desired size, feeding
tering capacity. Once fish have
should be reduced to a mainte-
ance ration.

Feeding rates can be estimated by
approximating fish weight based
on their length (Table 2). A feed-
ing 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 usu-
ally grow a little even on a main-
tenance diet because of the abun-
dance 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 min-
utes. 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 tempera-
tures fish do not feed well and
are easily stressed by poor water
quality. Feeding activity also
declines when temperatures drop
because fish metabolism decreas-
es. Fish do not feed at water tem-
peratures 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, dis-
eases, and/or oxygen depletions.

Aquatic plants
Aquatic plants not only add beau-
ty to a water garden but are also
effective filters and nutrient
absorbers. Plants such as sagit-
taria 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 trop-
cical 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 cut-
ting 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 mate-
rial effectively hold soil around
the plant roots but also allow
plants to absorb nutrients from
the water. Plants should be pot-
ted in a heavy clay soil, free of
organic matter, fertilizers and pes-
ticides. 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 sur-
fase. 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 plant-
ed in a single pot. Little fertiliza-
tion is needed for submerged
plants.

Many people construct water gar-
dens 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 mat-
ter they eat.

Many plants used in water gar-
dens 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 visi-
bility, 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 experience.

<table>
<thead>
<tr>
<th>Total length (inches)</th>
<th>10 fish weight</th>
<th>Goldfish</th>
<th>10 fish weight</th>
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<tbody>
<tr>
<td></td>
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| Table 2. Approximate length to weight relationships for carp and goldfish. | | |
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 non-native 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 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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**Table 3. Feeding rates, based on water temperature, for growth or maintenance rations.**

<table>
<thead>
<tr>
<th>Water temperature (°F)</th>
<th>Growth ration (% body weight/day)</th>
<th>Maintenance ration (% body weight/day)¹</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fish less than 1/2 pound</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 90</td>
<td>1.0</td>
<td>0</td>
</tr>
<tr>
<td>70 - 90</td>
<td>3.0</td>
<td>1.0</td>
</tr>
<tr>
<td>60 - 69</td>
<td>2.0</td>
<td>0.5</td>
</tr>
<tr>
<td>50 - 59</td>
<td>1.0</td>
<td>0.2</td>
</tr>
<tr>
<td>45 - 49</td>
<td>0.5</td>
<td>0</td>
</tr>
<tr>
<td>&lt; 45</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

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<td>0.2</td>
</tr>
<tr>
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<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

¹Feed only 5 days per week.

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