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AQUAPONICS: FISH SPECIES SELECTION

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According to the Oxford Dictionary, "aquaponics is an aquaculture system in which the waste produced by farmed fish or other aquatic animals supplies nutrients for plants grown hydroponically, which in turn purifies the water."

In other words, aquaponics is a two-crop agricultural system consisting of 1) vegetables or herbs; and 2) fish, with each "crop" playing a unique role. However, fish are often treated as "fuel" and not as a marketable crop, especially in small-sized commercial operations and with hobbyists. In most commercial aquaponic operations, farmed fish is not forgotten as a potential source of income, yet is often neglected. So how can an aquaponics operation achieve maximum economic viability?

To create maximum production, sustainability, and economic viability, the fish must be treated as a commercial crop and must be sold to generate income. In this model, fish are fed to achieve a marketable size. The waste produced by the fish feeds the plants, and fish are sold to offset feed and operation costs. Plants, in turn, filter water of excess nutrients and are also sold for profit. Plants that are sold are not meant to cover all costs and be the sole source of profits. It is the combined sales of fish and plants that allow a commercial operation to reach the goal of sustained profitability and economic viability.

If fish are not utilized as an income source in a business model, operating a hydroponic system is suggested instead. A common myth among hobbyists is that aquaponics is cheaper than hydroponics. Initial start-up costs for hydroponics can be much cheaper, as it requires fewer parts such as water or air pumps, filters, and fewer tanks. Hydroponics is also cheaper long-term since additional costs for fish or fish feed are not needed, along with reduced electricity and labor. With hydroponics, it is much easier to maintain optimal culture conditions for plants. Many fertilizer formulations are calibrated to provide accurate nutrient concentrations of each element.

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QUICK FACT: Nitrate production (via fish feed) is costly compared to fertilizers. A typical fish feed with 32 percent protein costs $485 per ton in bulk—or $15 to $18 per 40 pound bag when purchased by the bag. When fed to hybrid striped bass, 1 ton of 32 percent fish feed will provide 305 pounds of waste nitrates based on protein digestion and turnover rates. To obtain a similar nitrate load from the common farm fertilizer urea (46-0-0), only 628 pounds of urea is required and costs only $215 (50 pound bag of 46-0-0 at $17 per bag).

This publication ranks common aquaculture fishes—labeled from "Poor" to "Excellent"—depending on their suitability for use in a commercial aquaponic system. Species are ranked based on commercial production and profit potential. Some of the "poor" fish species are acceptable for home-use and consumption in a home hobby system, but not for optimal system performance. In general, "ideal" fish species are those that can reach market size in less than 1 year and before they begin their reproductive development.

POOR SPECIES FOR AQUAPONICS

Comet Goldfish:

Comet goldfish can be—and have been—used by homeowners or hobbyists. On a commercial scale, it is not a preferable option, as it has no real market value. The sale price does not offset the cost of feeding. In other words, feed costs are more than the fish are worth. For example, the comet goldfish farm gate price is 1.5 to 3 cents each. As an ornamental species, retail price is 16 cents for small fish and 31 cents for large fish. When considering that feed costs for 6 months is 28 to 33 cents to reach market size, comet goldfish are not profitable and should not be used in a business model.

Marine Fish Species:

QUICK FACT: Marine or brackish species, including red drum, cobia, flounder, Atlantic croaker, pompano, and marine baitfish (Figs. 1 and 2), are UNACCEPTABLE for aquaponics. Although they may have a high market value, production and survival of these species is not possible in the low salinity water required for aquaponics. Marine fish often requires culture salinities of 5 ppt, but most vegetables and herbs will die at salinity levels as low as 1 ppm.

Figure 1. Flounder

Figure 2. Red Drum

FAIR SPECIES FOR AQUAPONICS

Bluegill, Redear, or Hybrid Sunfish

Sunfish (Fig. 3) are a popular "sportfish" and an excellent table fare, with low initial cost at about 25 to 35 cents per 1 to 3 inch fingerling fish. Sunfish are easy to grow and can be spawned outdoors or in greenhouses by providing nest boxes and pea gravel. Sunfish readily accepts commercial diets but are still considered a poor choice in aquaponics.

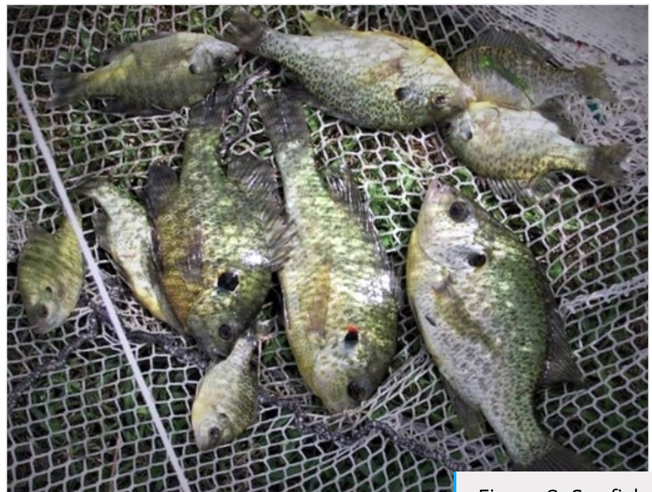

Figure 3. Sunfish

The biggest hindrance to using sunfish in aquaponics is that they are illegal to be sold as a food fish in some states, including Texas. As a reminder: Ideal fish species reach market size in less than a year and before they begin their reproductive development. Bluegill is a somewhat slow-growing fish and can take 2 to 2.5 years or more to reach a market size of 1 pound. With the slow, maturing bluegill, one crop every 2 or 3 years can be expected. Additionally, bluegill have a poor feed conversion ratio (FCR). On average, it takes 3.5 to 4.4 pounds of feed for every pound of weight gain. At a feed cost of $1.06 to $1.83 per pound, the cost of feed for every pound of fish weight is $3.71 to $8.05. With a dress out percentage at 27 percent for bluegill, the break-even price for bluegill fish for 1 pound of fillet is $13.74 to $29.81. These prices are too high and are not achievable with the current market.

Channel Catfish, Blue Catfish, or Hybrids

Catfish (Fig. 4) are widely known and have demonstrated market acceptability. They are the largest produced food fish in the U.S. fish industry. Catfish also have an excellent fillet yield and dress out percentage as a whole fish (e.g., gutted). Additionally, their FCR in tanks is good at 1.5 to 1.8 when carefully fed. However, the issue with catfish is a stagnant selling price of 85 to 95 cents per pound and a high-level of competition within an already wellestablished market. With estimated production costs of 80 to 88 cents per pound, producers must sell large volumes of fish to generate any substantial profit-income. With current catfish production and sale prices, it is difficult for a small aquaponic operation to be profitable. It is possible that catfish sales can offset feed costs, but not system costs or operational costs.

Figure 4. Channel Catfish

Additionally, catfish do not perform well in tanks, having a generally slower growth rate than in outdoor ponds and take up to 18 months for one production cycle, or to reach marketable size. This means less than one crop is generated per year. Catfish are also territorial, with males especially, which begin fighting when they reach 0.25 to 0.5 pound in size. Damage and disease induced by this aggressive behavior render the product unmarketable. High stocking densities can discourage fighting, but can also lead to poor water quality and the need for more intensive management practices. Also, disease prevalence increases dramatically in tanks, especially at high stocking densities. Catfish are prone to parasites and diseases, such as enteric septicemia of catfish (ESC), columnaris, *Aeromonas*, and proliferative gill disease. The high disease rate and inability to use medications for disease treatment in most aquaponics systems makes it extremely difficult to raise a crop of catfish to market size profitably in aquaponics systems.

GOOD SPECIES FOR AQUAPONICS

Largemouth Bass

The largemouth bass (Fig. 5) is widely recognized as a "sportfish," but is not a common food fish. Like the sunfish mentioned above, it is illegal to sell largemouth bass as food fish in some states, including Texas. In states where it is illegal to be marketed as a food fish, it can only be marketed as a sportfish. When sold as a high-end sportfish, largemouth bass can obtain $10 to $25 per pound live weight based on size (larger fish bring higher prices), but only $4 to $6 per pound as a live food fish—making this species "marginal" to "good."

Figure 5. Largemouth Bass

In an aquaponic system, largemouth bass do not tolerate small tanks as well as larger tanks. A minimum tank size of 1,200 gallons is recommended for growth and to reduce cannibalism. When fish are still small, growers must grade for size at least monthly to ensure that bigger fish are not cannibalizing on smaller ones.

The largemouth bass is very difficult to train to eat pellet feed and must be specially trained at a young age (small size) to consume an artificial diet in the hatchery. This process is expensive, since up to 60 percent of the fish crop may be lost during pellet training due to stress, disease, or starvation as some fish simply refuse to ever eat an artificial diet. Furthermore, this process isn't guaranteed and fish will easily revert to cannibalism. This results in a higher initial cost of the remaining crop in order to make up for losses during pellet-training. Pellet-trained largemouth bass can be 2 to 4 times more expensive than non-pellet-trained largemouth bass according to NCRAC (2000). For example, while sale prices for non-pellet trained largemouth bass is 35 cents for 1 to 2 inches, 68 cents for 2 to 4 inches, 94 cents for 4 to 6 inches, and $2.07 for 6 to 8 inches, prices for pellet-trained largemouth bass are 85 cents, $1.65, $2.43, and $6.19, respectively. Only pellet-trained largemouth bass can be used in aquaponics due to the reliance on artificial diets for efficient and cost-effective production.

Largemouth bass are very expensive to produce and takes about 18 months to reach a marketable size of 1.25 pounds, although larger sizes less than 2 pounds are frequently desired. However, their production times last 24 months or more. The slow growth rate of largemouth bass may be due to its poor FCR, according to research conducted by the University of Arkansas at Pine Bluff. They require a high-protein diet with a minimum of 40 percent protein content. Considering a 60 to 74 percent survival rate and FCR of 2.0 to 2.6 pounds of feed per pound of body weight, it then costs $4.17 per pound to produce, with a $4.54 per pound selling price to break even.

Largemouth bass have few specific diseases, but are prone to some common parasites and diseases such as columnaris and Aeromonas.

Koi

Koi is a non-traditional or novel fish species used in aquaponics. It can be a high-value species and is best sold as large individuals for ornamental ponds. Small individuals are of little value and are sold at farm gate prices of 20 to 45 cents for 1 to 3 inches pond run, while the retail price for small fish is about $5.99 each. Ideal market size is 1 to 3 pounds, with a value of $20 to $65 per fish, possibly more at that size. Unlike goldfish, koi can be sold for a profit but the market for koi is poorly defined and highly variable. It is not a high-volume sale fish, and producers must wait for the right buyer—and typically, only sell one or two fish at a time.

Because koi grows rapidly and requires a low-protein diet of 28 to 32 percent, koi is cheap to produce. A finished koi diet with pigments increases its aesthetic value. The feed conversion ratio is also reasonable, with 1.8 to 2.4 pounds of feed per pound of fish. Therefore, the production cost is 53 to 70 cents in feed costs to produce 1 pound of fish (plus $1.60 finish).

Additionally, koi can tolerate poor water quality such as temperatures of 32°F to 95°F (ideal range is 65°F to 75°F), dissolved oxygen (DO) of 2 ppm for short periods (ideal range is ≥5 ppm), and can tolerate a pH range between 5 to 9.

On the downside, koi are susceptible to many parasites. Examples of parasites include: Anchor worm, fish louse, monogenetic trematodes, and protozoan parasites such as Ich, *Trichodina*, and *Chilodonella*. Koi are also susceptible to infections and viral diseases such as koi ulcer disease caused by *Aeromonas salmonicida* bacteria, koi herpes virus, and carp virus's spring viremia.

EXCELLENT SPECIES FOR AQUAPONICS

Tilapia

Tilapia (Fig. 6) are the most popular freshwater fish in commercial aquaculture and are widely used in aquaponics. Numerous (>300) species exist worldwide. Although, only three are legal in Texas: Mozambique Tilapia (*Oreochromis mossambicus*), Nile Tilapia (*Oreochromis niloticus*), and Blue Tilapia (*Oreochromis aureus*). Nile and Blue Tilapia are preferred due to their ideal market size of 1 pound, providing the 6-ounce filet size desired in restaurants. However, being a non-native species originating from Africa, tilapia requires an exotic species culture permit from Texas Parks and Wildlife Department.

Figure 6. Tilapia

Tilapia are omnivores, meaning they can eat both plant- and animal-based feed, making great candidates for alternative feeds—such as high-protein plants (duckweed and *Azolla* spp.). Conversely, as omnivores, tilapia can and will eat other fish, especially their own young. Tilapia should be graded for size during breeding to increase offspring survival. According to FAO, fish that are less than 6 inches eat smaller fish, though they are generally too slow when larger than 6 inches and cease to be a problem.

QUICK FACT: Most tilapia species are mouthbrooders, meaning they carry fertilized eggs and newly hatched fry in their mouth to protect them from predators. Although tilapia reach market size rather quickly, mouthbrooding causes lost production time as the fish cannot feed effectively while carrying eggs or fry in their mouth.

Tilapia is easy to raise in small- to extremely large-scale aquaponic systems. They adapt very well to tanks and tolerate high stocking densities (up to 3/4 pound per gallon at high aeration rates). Interestingly, at low stocking densities, male tilapia can be very territorial and aggressive. Therefore, young fish should be kept at high densities in grow-out tanks. Occasionally, fish populations may need to be thinned to the desired stocking density due to their high fecundity, which may lead to poor water quality and other issues.

In terms of production characteristics, tilapia ranks high and is extremely desirable in an aquaponic system. Tilapia can be harvested in 6 to 8 months with a potential for two fish harvests per year when temperatures are managed to maximize growth. Compared to other fish species, tilapia survives well on a low-protein diet of 26 to 32 percent protein and 4 to 6 percent lipid. The feed conversion rate in tanks is highly sufficient with 1.3 to 1.8 pounds of feed required for 1 pound of fish weight gain. In ponds, tilapia is estimated to cost 51 to 60 cents per pound of fish, compared to $1.51 to $1.79 per pound of fish in tanks. Tilapia are already priced out of most traditional markets at these tank production costs because the break-even price is $4.57 to $5.42 per pound fillets. Tilapia are often sold whole-gutted or live. For fillets, tilapia dress out percentage is around 33 percent and goes up to 66 percent for the whole fish without its head—and 86 percent with its head.

Unfortunately, tilapia market prices have been depressed by cheap imports with lower production costs flooding U.S. markets, resulting in market prices lower than what tilapia can be produced at in aquaponics systems. However, there are many U.S. small, niche and boutique markets, where farm-grown tilapia can achieve higher prices and make it profitable for aquaponics growers. This is possible because more Americans are willing to pay higher prices for fresh, local or U.S. sustainably grown tilapia that has not been subjected to antibiotics or other medications.

Tilapia are tolerant of poor or marginal water quality, and diseases in tilapia are not as common as the fish is resistant to many pathogens and parasites. They can survive in water with a wide pH range between 5 to 10, high water temperatures, low (DO), and high ammonia—albeit for short periods. Unfortunately, most species are intolerant of low water temperatures, tolerating 57°F for only a few days, but they stop feeding if water temperatures are below 63°F. Many species of tilapia, including Mozambique Tilapia, will begin to die when water temperatures drop below 54°F. On the other hand, Blue Tilapia can tolerate 48°F. In colder regions, it is best to avoid raising tilapia in winter months unless the water is heated.

Hybrid Striped Bass

A hybrid between striped and white bass, hybrid striped bass (HSB) (Fig. 7) retains the best traits of its parent species (SRAC No. 300). HSB has improved tolerance to broad ranges of water quality and is not able to reproduce, which is a desirable trait that reduces loss of production due to gamete development and spawning (see tilapia). However, the inability to reproduce means producers must buy new fingerlings (55 to 70 cents for 3 to 5 inches per fish size) for each production cycle and cannot produce their own fish on a small scale.

HSB are well adapted to tanks and can tolerate stocking densities of 0.33 to 0.5 pound per gallon. Tanks larger than 400 gallons are recommended for HSB in aquaponics to support rapid growth and limit water quality issues due to high densities. Additionally, HSB can be grown to 1.5 pounds in tanks as small as 150 gallons.

Figure 7. Hybrid Striped Bass (HSB)

In general, HSB are expensive to produce, with 70 percent of production costs being associated with feed. The FCR is 2.5 to 2.8 pounds of feed per pound of fish, resulting in production costs of 97 cents to $1.19 per pound of fish in feed costs; and $2.10 to $2.39 per pound in total production costs, which is not very efficient. Furthermore, HSB take 12 to 14 months to reach a market size of 1.5 to 2.5 pounds from 3 to 5 inch stockers, and requires feed that contains 36 to 40 percent protein and 10 to 12 percent lipid, costing $775 to $850 per ton in bulk.

At a dress out percentage of 45 for HSB, the break-even sale price should be $4.66 to $5.31 per pound of fillets. With current market prices of $2.58 to $3.02 per pound of whole fish in bulk and fillets selling at $8.99 to $9.99 per pound, HSB are currently a high-market value species and a profitable enterprise. In niche markets such as Asian restaurants, whole fish can procure $6 to $8. However, the market is not well defined. This species is not commonly seen in Texas grocery stores, with 81 percent of production shipped whole on ice to the East Coast.

HSB can tolerate water temperatures between 39°F and 92°F even though the ideal range is 73°F to 81°F. HSB can also tolerate DO of 1 ppm for short periods (ideal DO is >4 ppm), alkalinity of 20 to 100 ppm (ideal value is >100), water hardness of 20 to 100 ppm (ideal is minimum 40, preferably >100), and a pH of 2.5 for short periods; pH 6 is not an issue for HSB, but the ideal pH range is 7 to 8.5.

QUICK FACT: Hybrid Striped Bass do not efficiently digest food at high water temperatures (>86°F), making them more susceptible to bloating. Gas from partially digested feed accumulates and food may not normally pass, resulting in symptoms such as floating upside down in the tank. Recovery from bloating depends upon feed composition, fish size, and the duration of the high water temperatures. One approach to address bloating in HSB is to insert the eraser end of a pencil in the mouth to release gas from the stomach and intestine. A better approach is to reduce feed when water temperatures are above 86°F to avoid bloating.

Few disease issues are observed in HSB when water quality is maintained correctly. Known bacterial diseases are columnaris, motile aeromonas septicemia (MAS), and *Streptococcus iniae* (Fig. 8).

Figure 8. Lesions forming on side of hybrid striped bass caused by the bacterium *Streptococcus iniae.*

QUICK FACT: Poor water quality can increase susceptibility to diseases, such as those caused by aeromonas. Such diseases should be avoided, even if some species have a high tolerance.

Table 1. Acceptable and desirable ranges of various water quality parameters for productive fish growth.

	Acceptable	Desirable
pH	5.5 to 10	6.5 to 9.0
Alkalinity	20 to 400 ppm	50 to 150 ppm
Calcium	>10 ppm	>20 ppm
Hardness	>20 ppm	50 to 150 ppm
Iron	Any ppm ferric	<1 ppm ferric
Chloride	10X nitrate level	10X nitrate level
Nitrate	<90 ppm	<50 ppm
Nitrite	1:10 chloride	<0.1 ppm

Table 2. Fish production time, costs, and associated market value for aquaponics production.

Species[1]	Time to Market (Months)	Feed Cost ($)	Market Size (lbs.)	Market Price ($)
Comet Goldfish	6	$0.30-$0.34/fish	N/A[2]	$0.16-$0.31/fish
Sunfish	24 to 30	$1.06-$1.83/lb.	>1	$13.95/lb. fillet[3]
Catfish	18	$0.80-$0.82/lb.	>1.5	$0.85-$1.25/lb. whole
Largemouth Bass	18	$4.17/lb.	>1.25	$10-$25/lb. live[4] $4-$6/lb. whole[5]
Koi	Variable	$0.53-$0.70/lb.[6]	1 to 3	$20-$65/fish
Tilapia	6 to 8	$1.51-$1.79/lb.	1 to 1.25	?
Hybrid Striped Bass	12 to 14	$0.97-$1.19/lb.	1.5 to 2.5	$3.30-$3.60/lb. whole $8.99-$9.99/lb. fillet

[1]Color code description: Red = Poor; Orange = Fair; Yellow = Good; Green = Excellent
[2]Sizes ranges from small to large.
[3]Sunfish are illegal to sell as a food fish in some states.
[4]Live weight sportfish.
[5]Live weight food fish. Largemouth bass are illegal to sell as food fish in some states.
[6]Additional $1.60 finishing feed cost per fish.