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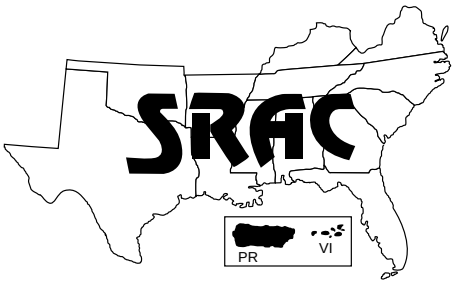

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Bullfrog Culture

C. Greg Lutz[1] and Jimmy L. Avery[2]

Many frog species are edible, but the North American bullfrog *Rana catesbeiana* is generally considered the most suitable for production. Frog culture has been researched in a number of countries, but there has been little commercial development. Manage-ment and husbandry practices have been developed to allow continuous bullfrog production in tropical climates, but several major problems with frog culture remain unsolved. These factors have severely limited commercial production, even in tropical regions with suitable temperatures for year-round growth. When combined with comparatively high land and labor costs and limited growing seasons, these constraints have effectively prevented the development of commercially viable frog culture in the United States.

Most problems in frog culture involve nutrition and disease management. Up to 520 grams (1.15 pounds) of live food are required to produce a single 185-gram (0.41-pound) bullfrog destined for the frog leg market (Table 1.). Brazilian researchers have developed artificial feeds, but bullfrogs will not voluntarily consume artificial diets without the appropriate combination of movement, texture and flavor. As a result, production of live feed

Adult bullfrog.

becomes a full-time activity in any frog farming operation. Recommended feeding practices can occasionally result in sanitation problems, and bullfrogs frequently become infected with opportunistic bacteria, even under apparently sanitary conditions.

Commercial frog culture has not developed strongly because rearing these aggressive but fragile amphibians through a complicated life cycle is technically difficult. Approaches to frog culture that have been tried include semi-natural systems, controlled artificial pond systems, and indoor laboratory culture for research. Semi-natural systems often consist of little more than earthen ponds with enclosures to keep frogs in and predators out. These systems usually have major problems with predation, cannibalism, diseases, limited food sources, water quality / sanitation, and fluctuating temperatures.

Artificial systems also have problems with cannibalism and diseases, as well as inadequate nutrition because of few alternatives to live feed. Nonetheless, of the few commercial frog culture operations currently in existence, most

Table 1. Typical growth and feed consumption of cultured bullfrogs in outdoor pens, 25 to 30º C. Values represent mid-month averages.

Age in months (post-metamorphosis)	Avg. weight (g)	Approx. daily consumption (g)
0	5	-
1	10	0.50
2	22	1.09
3	35	1.22
4	50	1.72
5	75	2.63
6	105	3.67
7	140	4.90
8	175	6.12

Source: Culley, D.D., Jr., Baldwin, W.J. and Roberts, K.J. 1981. The feasibility of mass culture of the bullfrog in Hawaii. Louisiana State University. Sea Grant Publication No. LSU-81-004. Baton Rouge. 26 pp.

[1]Louisiana Cooperative Extension Service
[2]Louisiana State University Agricultural Center

employ artificial pond systems. All of these businesses are operating in developing countries with low land and labor costs, and in tropical regions where production can be sustained year round. Most of these operations have developed the technical expertise and culture facilities to produce large numbers of marketable frogs, but high costs make it hard to compete with frogs harvested in the wild.

Culture techniques

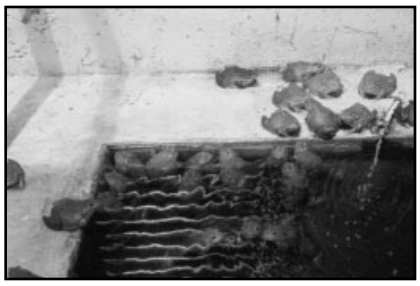
Because most research has focused on refining controlled artificial pond systems, this approach will be described in this fact sheet. Bullfrog production requires special facilities and culture practices for various life stages, including egg incubation, tadpole culture, grow-out of young frogs, and maintenance and breeding of adult broodstock. For all life stages the most important day-to-day management consideration is adequate sanitation to prevent bacterial disease. Sanitary and nutritionally complete feed also must be provided for each phase of the life cycle.

Broodstock management

The healthiest and fastest growing frogs should be selected for broodstock whenever possible. Older breeders should be culled and new breeders selected on a regular basis. The recommended sex ratio is 1 male to 5 females. Male bullfrogs can be differentiated from females by their larger typanums (the drum-like plates of skin on the sides of their heads), which usually are larger than the diameter of their eyes. Breeders should be stocked at a density of four per square meter (three per square yard) in large, open pens designed for maintenance and spawning.

Breeding pens should be as large as possible, but at least 6 m by 6 m (20 feet by 20 feet). A typical pen for natural breeding is constructed of fine mesh walls extending 1.5 m (5 feet) above ground level and 15 cm (6 inches) beneath the ground. Pens should be at least partially covered with shade cloth. A breeding pen should include one or more "islands," preferably covered with concrete or a rubber liner material. Islands should be surrounded by a pond or network of canals 15 to 20 cm (6 to 8 inches) deep constructed of concrete or lined with plastic and supplied with clean, flowing water. In the center of the island(s), small pools are formed to hold live feed animals such as fish or tadpoles. These feeding pools should also be supplied with flowing water. In temperate regions, some amount of natural habitat with appropriate soils and deeper pond areas (more than 1.5 m, 5 feet) must be provided where breeding frogs can hibernate during the winter.

Feeding pools are not required if terrestrial feed animals such as crickets, worms or fly pupae are used. Terrestrial feeds are more difficult to keep in a centralized area, however, and can cause sanitation problems because it is difficult to collect and remove dead or uneaten feed. With any food type, breeders should be offered 5 to 10 percent of their body weight per day. Uneaten feed must be removed at each new feeding, and all ponds, pools and canals should be flushed daily with 5 mg/L chlorine. All exposed artificial surfaces should be treated and washed down daily. This concentration of chlorine will not harm the frogs, and if done at the same time each day frogs will become accustomed to this activity. Aquatic plants should be discouraged except in breeding frames (see below) because they interfere with daily cleaning activities and with inspection of frogs for diseases. Ponds, pools and canals should be drained and scrubbed once each month.



Breeding pen.

Breeding sites can include small, specially constructed ponds, or the canals themselves. Water in these breeding areas should be continuously exchanged. Shallow (15-cm, 6-inch) wood frames with screen bottoms are placed in the water, with several potted emergent plants or floating plants within the frames to attract male breeders.

Tadpole culture

Hatchery: Eggs should be collected daily from the breeding pen, transported to the hatchery, and placed in shallow (1- to 2-cm, 0.4- to 0.8-inch) floating screen trays in incubation tanks. At this time, the number of eggs can be estimated by counting eggs within 4- or 9-square cm (1- or 2-square inch) sections of the tray and extrapolating to the total tray area. Egg density should be adjusted to about 5,000 eggs/square meter (4,200 eggs/square yard) for incubation. Incubation tank dimensions are typically 1 to 2 square meters (1.2 to 2.4 square yards) in surface area by 15 to 20 cm (6 to 8 inches) deep. Water should be replaced about twice a day, with inflow introduced as a fine spray, but not directly on the egg mass. Spraying is critical if pond water is used, because tadpoles are particularly susceptible to gas bubble disease caused by the oxygen supersaturation associated with afternoon algal photosynthesis.

Egg collection.

The hatchery itself need not follow any particular design. Water quality parameters suitable for most warmwater fish should also be adequate for tadpoles, although total hardness should be no less than 50 mg/L and temperature should be maintained between 20 and 28º C (68 to 82º F). Clear roofing is desirable to allow sunlight to support algal growth in the tadpole rearing tanks. If water is supplied from wells or treated municipal sources, more complete nutritional supplements may be required in tadpole diets to make up for a lack of algal growth and natural microorganisms that would be present in pond water.

After 4 to 5 days, hatching should begin. Then the hatching tray is removed and the larval tadpoles disperse freely through the tank. At least partial exposure to sunlight is critical at this time to encourage algal growth on the sides of the tank. The inflowing water spray should be adjusted to cover more of the tank surface. One day after hatching begins, lettuce leaves that have been soaked in water for 12 to 24 hours should be introduced into the tank. Active feeding should be observed by the seventh day after hatching. Food must be present at all times once feeding begins. After feeding has begun, prepared diets with approximately 45 percent crude protein should be offered at 4- to 6-hour intervals (see Table 2). A mixture of wheat bran and minced fish, bound with corn starch or gelatin, has been used in some hatcheries. Commercial salmon starter has also been successful for rearing tadpoles. Although an average spawn should contain 3,000 to 5,000 eggs, a large female bullfrog can lay up to 20,000 eggs. If density exceeds 4,000 larvae per square meter (3,300 per square yard) of surface area 12 days after hatching, some tadpoles can be transferred to another tank or harvested to serve as food for small frogs. A large net with the finest available mesh, supported in a bucket or tray of water, should be used for transferring tadpoles.

Table 2. Diet formulation for laboratory culture of larval frogs.

Ingredient	Percentage by weight
Shrimp meal	16.5
Fish meal	22.0
Soy protein	5.5
Yeast protein	16.5
Rice bran	21.0
Whey	5.0
Fish oil	2.0
Fish solubles	5.0
Vitamin premix	2.0
Linolenic acid	0.5
Binder	4.0

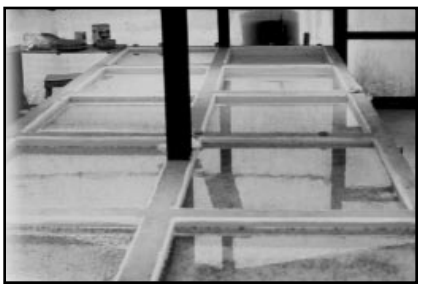
Ingredients must be thoroughly mixed. The resultant fine powder can be fed directly to very young larval tadpoles. For larger tadpoles, mix dry ingredients with sufficient water to form a thick paste. Spread paste on both sides of a small piece of window screen. Dip screen in a 20 percent solution of calcium chloride for 1 minute. Use or store refrigerated for up to 4 weeks.

Source: Culley, D.D., Jr., Meyers, S.P. and Doucette, A.J., Jr. 1977. A high density rearing system for larval anurans. *Lab Animal*, 6:34-41.

Approximately 21 days after hatching, tadpoles should be transferred to tadpole culture ponds or to wire-framed screen baskets in recirculating systems. Survival during this period varies substantially, but an overall level of 65 percent is considered very good. Before it is used again the culture tank should be disinfected with chlorine (5 mg/L), scrubbed, drained and dried. Inadequate or inefficient hatchery facilities often constrain commercial operations. Considering that a single large spawn may require several tanks of 1 square meter (1.2 square yards) each for up to 27 days, a facility that collects an average of one spawn per day requires up to 81 hatching tanks.

Pond Culture: Tadpole grow-out ponds should be constructed of concrete or outfitted with plastic liners. Tadpole ponds may range in size from 10 to 200 square meters (12 to 240 square yards), with a recommended depth of 0.5 to 0.7 meters (1.6 to 2.3 feet). Pond size may be limited by the requirement for one complete water exchange each day, although daily turnover can be substantially less if water quality parameters and general health remain good. Ponds should be filled with clean water and "seeded" with water from established ponds to encourage growth of attached algae and microorganisms that are natural food for tadpoles. No more than 3 days before stocking, these inoculated ponds should be temporarily drained to remove predatory aquatic insects and immediately refilled in preparation for stocking. Insecticides or oil treatments should not be used for insect control in tadpole ponds.

Tadpoles transferred from hatchery tanks should be stocked at densities of 100 to 200 per cubic meter (75 to 150 per cubic yard). At higher densities, development is retarded, size at metamorphosis is reduced, and mortality increases. Once or twice daily artificial feed mixtures, as prepared for use in hatchery tanks, are placed at 2-meter (6.5-foot) intervals, ideally in a horizontal orientation at mid-depth. However, natural algal, fungal and bacterial growth also provides essential nutrition for developing tadpoles. Recent research in Mexico demonstrated that prepared feeds for bullfrog tadpoles could be reduced by up to 50 percent when phytoplankton is abundant without affecting growth or metamorphosis. After 5 weeks, collection of newly metamorphosed frogs can begin. Sections of cut pipe placed at regular intervals along the shoreline provide cover and attract newly formed frogs. These pipes should



Larval tadpole tanks.

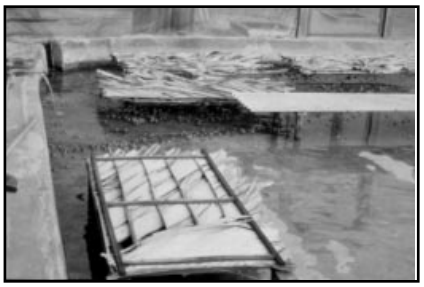
be checked every 3 hours to collect frogs for transfer to grow-out facilities. Seven weeks after stocking, the pond should be partially drained and remaining frogs and slow-growing tadpoles harvested with seines or dip nets. These can be used as food for larger frogs in grow-out pens. Each tadpole pond should be drained 7 weeks after stocking and cleaned, chlorinated and dried thoroughly before its next use.

Frog grow-out

Successful intensive frog culture requires artificial surfaces that can be cleaned daily. In Brazil producers have experimented with high density confined grow-out in concrete vats. However, most facilities in tropical regions throughout the world rely on outdoor pens similar to the breeding pens described above.

Many materials have been used in grow-out pens, but each seems to have some associated problems. Concrete may cause skin abrasions for bullfrogs and increase problems with bacterial infection. Some forms of vinyl and plastic can be too slippery and make it difficult for frogs to move about. Geotextiles or pond liner materials may be the best option in many situations, if available at acceptable prices. As with breeding pens, in temperate regions the typical grow-out pen will not be suitable for hibernation, and that substantially limits the growing and marketing seasons.

The size and shape of grow-out pens can vary greatly, but all rely on large exposed "islands" surrounded by or adjacent to flowing water. Water temperature during grow-out must be kept between 20 and 28º C (68 and 86º F). At least 25 percent of the culture area should be shaded to reduce sunlight 75 percent. Feeding pools should be 2 to 4 square meters (2.4 to 4.8 square yards) by 2 to 4 cm (0.8 to 1.6 inches) deep. Place them in the middle of islands if live aquatic feeds such as tadpoles or top minnows (*Gambusia* or *Poecilia*) will be used. Small crawfish (2 to 7 cm, 0.75 to 1.5 inches) make an excellent live food for bullfrogs, but are rarely available in tropical regions where commercial frog culture is most economically feasible. Feeding pools also should be supplied with flowing water for sanitation purposes.



Concrete pen with 2,000, 1-month old frogs.

Culture pens can be 10 to 100 square meters (12 to 120 square yards) in area. After they are taken from tadpole ponds, young frogs can be stocked in culture pens at up to 50 per square meter (42 per square yard). To minimize cannibalism, avoid stocking large and small frogs together. Many frogs will try to eat any prey they can fit into their mouths, and during the first several months of grow-out cannibalism can cause losses of 10 to 30 percent. Considerable space will appear to be wasted, since frogs prefer to sit in tight groups during most of the day. Nonetheless, density should be reduced to 20 per square meter (17 per square yard) of total area as frogs reach an average weight of roughly 60 grams (2 ounces). As frogs are removed they can be grouped by size to reduce cannibalism.

If the primary market product will be frog legs, harvest can begin when individual frogs reach approximately 175 grams (6 ounces), which should be in about 6 months. If skins are also to be used for leather, frogs can be grown to 250 grams (9 ounces) or even larger. Sanitation procedures for grow-out pens are the same as for breeding pens—open water must be chlorinated and exposed surfaces must be washed down. Uneaten feed must be removed promptly to prevent problems with bacterial outbreaks. During cleaning, frogs should be visually inspected. Ill or abnormal individuals must be removed and examined to identify specific disease problems and avoid potential outbreaks.

Commercial feasibility

The quantity and price of imported frog legs in the United States are both highly variable and no clear trends in supply or demand have been evident during the past decade. More than 2,100,000 kg (4,400,000 pounds) were imported annually in the late 1980s; however, imports have ranged between 500,000 kg (1,100,000 pounds) and 1,500,000 kg (3,300,000 pounds) in recent years. The value of frog leg imports is about $6 to $7 per kg ($2.70 to $3.20 per pound).

Frog products find their way from large importers and brokers to U.S. consumers through established seafood marketing channels. Major frog leg suppliers include Bangladesh, Belgium, China, Indonesia, Japan, Mexico, the Netherlands and Taiwan. Most current supplies are harvested in the wild, although there is some farm production in tropical countries with extremely low land and labor costs. In the southeastern U.S., commercial frog leg production is limited by the technical and labor requirements, short growing season, and unsolved disease and nutritional problems; for these reasons production costs could be as high as $28 per kg ($12.70 per pound).

Certain approaches to commercial frog culture in tropical regions can be adapted for laboratory-scale production of small frogs for research and teaching. Adaptations could also be used to improve southeastern U.S. farm pond habitats for frogs, although other pond uses might be adversely affected. However, economic feasibility will be determined by prevailing market conditions.

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