= American bullfrog =

The American bullfrog (Lithobates catesbeianus or Rana catesbeiana) , often simply known as the bullfrog in Canada and the United States , is an amphibious frog , a member of the family Ranidae , or ? true frogs ? . This frog has an olive green back and sides blotched with brownish markings and a whitish belly spotted with yellow or grey . The upper lip is often bright green and males have yellow throats . It inhabits large , permanent water bodies , such as swamps , ponds , and lakes , where it is usually found along the water 's edge . The male bullfrog defends a territory during the breeding season . His call is reminiscent of the roar of a bull , which gives the frog its common name . This frog is native to southern and eastern parts of the United States and Canada , but has been widely introduced across other parts of North , Central and South America , Western Europe , and parts of Asia , and in some areas is regarded as an invasive species .

The bullfrog is harvested for use as food in North America and in several countries into which it has been introduced . It is also cultured in controlled environments , though this is a difficult and not always successful undertaking . Some international trade in frog legs occurs for human consumption . Bullfrogs are used in biology classes in schools for dissection and are sometimes kept as pets .

= = Taxonomy = =

Some authorities use the scientific name , Lithobates catesbeiana , although others prefer Rana catesbeiana . A systematic review of the Holaractic true frogs in 2016 used Rana catesbeiana , as does AmphibiaWeb , an online compendium of amphibian names and information available at http : / / amphibiaweb.org / .

= = Etymology = =

The specific name , catesbeiana (feminine) or catesbeianus (masculine) , is in honor of English naturalist Mark Catesby .

= = Description = =

The dorsal (upper) surface of the bullfrog has an olive @-@ green basal color , either plain or with a mottling and banding of grayish @-@ brown . The ventral (under) surface is off @-@ white blotched with yellow or gray . There is often a marked contrast in color between the green upper lip and the pale lower lip . The teeth are tiny and are useful only in grasping . The eyes are prominent with brown irises and horizontal almond @-@ shaped pupils . The tympani (eardrums) are easily seen just behind the eyes and the dorsolateral folds of skin end close to them . The limbs are blotched or banded with gray . The forelegs are short and sturdy and the hind legs long . The front toes are not webbed , but the back toes have webbing between the digits with the exception of the fourth toe which is unwebbed .

Bullfrogs are sexually dimorphic , with males being smaller than females and having yellow throats . Males have tympani larger than their eyes , whereas the tympani in females are about the same size as the eyes . Bullfrogs measure about 3 @.@ 6 to 6 in (9 to 15 cm) from snout to vent . They grow fast in the first eight months of life , typically increasing in weight from 5 to 175 g (0 @.@ 18 to 6 @.@ 17 oz) , and large mature individuals can weigh up to 500 g (1 @.@ 1 lb) . In some cases bullfrogs have been recorded as attaining 800 g (1 @.@ 8 lb) and measuring up to 8 in (20 cm) in length .

= = Distribution = =

The bullfrog is native to eastern North America . Its natural range extends from the Atlantic Coast to as far west as Oklahoma and Kansas . It is not found on offshore islands near Cape Cod and is largely absent from Florida , Colorado , Nebraska , South Dakota , and Minnesota . It has been

introduced into Nantucket island , Arizona , Utah , other parts of Colorado and Nebraska , Nevada , California , Oregon , Washington , and Hawaii . In these states , it is considered to be an invasive species and there is concern that it may outcompete native species of amphibians and upset the ecological balance . It is very common in California , where it is believed to pose a threat to the California red @-@ legged frog and is considered to be a factor in the decline of that vulnerable species .

Other countries into which the bullfrog has been introduced include Mexico , the western half of Canada , Cuba , Jamaica , Italy , the Netherlands , and France . It is also found in Argentina , Brazil , Uruguay , Venezuela , Colombia , China and Japan . The reasons for introducing the bullfrog to these countries have included their intentional release , either to provide a source of food or as biological control agents , the escape of frogs from breeding establishments , and the escape or release of frogs kept as pets . Conservationists are concerned the bullfrog is relatively immune to the fungal infection chytridiomycosis and as it invades new territories , it may assist the spread of this lethal disease to more susceptible native species of frog .

= = Breeding behavior = =

The bullfrog breeding season typically lasts two to three months . A study of bullfrogs in Michigan showed the males arriving at the breeding site in late May or early June , and remaining in the area into July . The territorial males that occupy sites are usually spaced some 3 to 6 m (9 @.@ 8 to 19 @.@ 7 ft) apart and call loudly . At least three different types of calls have been noted in male bullfrogs under different circumstances . These distinctive calls include territorial calls made as threats to other males , advertisement calls made to attract females , and encounter calls which precede combat .

The bullfrogs have a prolonged breeding season , with the males continuously engaging in sexual activity throughout . Males are present at the breeding pond for longer periods than females during the entire season , increasing their chances of multiple matings . The sex ratio is typically skewed toward males . Conversely , females have brief periods of sexual receptivity during the season . In one study , female sexual activity typically lasted for a single night and mating did not occur unless the females initiated the physical contact . Males only clasp females after they have indicated their willingness to mate . This finding refutes previous claims that a male frog will clasp any proximate female with no regard to whether the female has consented .

These male and female behaviors cause male @-@ to @-@ male competition to be high within the bullfrog population and sexual selection for the females to be an intense process . Kentwood Wells postulated leks , territorial polygyny , and harems are the most likely classifications for the bullfrog mating system . Leks would be a valid description because males congregate to attract females , and the females arrive to the site for the purpose of copulation . In a 1980 study on bullfrogs in New Jersey , the mating system was classified as resource @-@ defense polygyny . The males defended territories within the group and demonstrated typical physical forms of defense .

= = = Choruses = = =

Male bullfrogs aggregate into groups called choruses . The male chorus behavior is analogous to the lek formation of birds , mammals , and other vertebrates . Choruses are dynamic , forming and remaining associated for a few days , breaking down temporarily , and then forming again in a new area with a different group of males . Male movement has experimentally been noted to be dynamic . In the Michigan study , the choruses were described as ? centers of attraction ? in which their larger numbers enhanced the males ? overall acoustical displays . This is more attractive to females and also attractive to other sexually active males . Choruses in this study were dynamic , constantly forming and breaking up . New choruses were formed in other areas of the site . Males moved around and were highly mobile within the choruses .

A review of multiple studies on bullfrogs and other anurans noted male behavior within the groups changes according to the population density of the leks . At higher population densities , leks are

favored due to the difficulty in defending individual territories among a large population of males . This variance causes differences in how females choose their mates . When the male population density is low and males maintain clearer , more distinct territories , female choice is mostly determined by territory quality . When male population density is higher , females depend on other cues to select their mates . These cues include the males ? positions within the chorus and differences in male display behaviors among other determinants . Social dominance within the choruses is established through challenges , threats , and other physical displays . Older males tend to acquire more central locations while younger males were restricted to the periphery .

Chorus tenure is the number of nights that a male participates in the breeding chorus . One study distinguishes between chorus tenure and dominant tenure . Dominant tenure is more strictly defined as the amount of time a male maintains a dominant status . Chorus tenure is restricted due to increased risk of predation , lost foraging opportunities , and higher energy consumption . Calling is postulated to be energetically costly to anurans in general . Energy is also expended through locomotion and aggressive interactions of male bullfrogs within the chorus .

= = = Aggressive behavior = = =

To establish social dominance within choruses , bullfrogs demonstrate various forms of aggression , especially through visual displays . Posture is a key factor in establishing social position and threatening challengers . Territorial males have inflated postures while nonterritorial males remain in the water with only their heads showing . For dominant (territorial) males , their elevated posture reveals their yellow @-@ colored throats . When two dominant males encounter each other , they engage in a wrestling bout . The males have their venters clasped , each individual in an erect position rising to well above water level . The New Jersey study noted the males would approach each other to within a few centimeters and then tilt back their heads , displaying their brilliantly colored gular sacs . The gular is dichromatic in bullfrogs , with dominant and fitter males displaying yellow gulars . The New Jersey study also reported low posture with only the head exposed above the water surface was typical of subordinate , or nonterritorial males , and females . High posture was demonstrated by territorial males , which floated on the surface of the water with their lungs inflated , displaying their yellow gulars . Males optimize their reproductive fitness in a number of ways . Early arrival at the breeding site , prolonged breeding with continuous sexual activity throughout the season , ownership of a centrally located territory within the chorus , and successful movement between the dynamically changing choruses are all common ways for males to maintain dominant , or territorial , status within the chorus . Older males have greater success in all of these areas than younger males . Some of the males display a more inferior role , termed by many researchers as the silent male status . These silent males adopt a submissive posture , sit near resident males and make no attempt to displace them . The silent males do not attempt to intercept females but are waiting for the territories to become vacant . This has also been called the alternate or satellite male strategy .

= = Growth and development = =

After selecting a male , the female deposits eggs in his territory . During the mating grasp , or amplexus , the male rides on top of the female , grasping her just behind her fore limbs . The female chooses a site in shallow water among vegetation , and lays a batch of up to 20 @,@ 000 eggs , and the male simultaneously releases sperm , resulting in external fertilization . The eggs form a thin , floating sheet which may cover an area of 0 @.@ 5 to 1 m2 (5 @.@ 4 to 10 @.@ 8 sq ft) . The embryos develop best at water temperatures between 24 and 30 ° C (75 and 86 ° F) and hatch in three to five days . If the water temperature rises above 32 ° C (90 ° F) , developmental abnormalities occur , and if it falls below 15 ° C (59 ° F) , normal development ceases . Newly hatched tadpoles show a preference for living in shallow water on fine gravel bottoms . This may reflect a lesser number of predators in these locations . As they grow , they tend to move into deeper water . The tadpoles initially have three pairs of external gills and several rows of labial teeth

. They pump water through their gills by movements of the floor of their mouths , trapping bacteria , single @-@ celled algae , protozoans , pollen grains , and other small particles on mucus in a filtration organ in their pharanges . As they grow , they begin to ingest larger particles and use their teeth for rasping . They have downward @-@ facing mouths , deep bodies , and tails with broad dorsal and ve ntral fins .

Time to metamorphosis ranges from a few months in the southern part of the range to three years in the north where the colder water slows development . Maximum lifespan in the wild is estimated to be eight to ten years , but one frog lived for almost sixteen years in captivity .

= = Feeding = =

Bullfrogs are voracious , opportunistic , ambush predators that prey on any small animal they can overpower and stuff down their throats . Bullfrog stomachs have been found to contain rodents , small reptiles , amphibians , crayfish , birds , and bats , as well as the many invertebrates , such as insects , which are the usual food of ranid frogs . These studies revealed the bullfrog 's diet to be unique among North American ranids in the inclusion of a large percentage of aquatic animals , such as fish , tadpoles , ram 's horn snails , and dytiscid beetles . Bullfrogs can capture large , strong prey because of the powerful grip of their jaws after the initial ranid tongue strike . The bullfrog is able to make allowance for light refraction at the water @-@ air interface by striking at a position posterior to the target 's perceived location . The comparative ability of bullfrogs to capture submerged prey , compared to that of the green frog , leopard frog , and wood frog (L. clamitans , L. pipiens , and L. sylvaticus , respectively) was also demonstrated in laboratory experiments .

Prey motion elicits feeding behavior . First , if necessary , the frog performs a single , orienting bodily rotation ending with the frog aimed towards the prey , followed by approaching leaps , if necessary . Once within striking distance , the bullfrog begins its feeding strike , which consists of a ballistic lunge (eyes closed as during all leaps) that ends with the mouth opening . At this stage , the fleshy , mucous @-@ coated tongue is extended towards the prey , often engulfing it , while the jaws continue their forward travel to close (bite) just as the tongue is retracted . Large prey that do not fit entirely into the mouth are stuffed in with the hands . In laboratory observations , bullfrogs taking mice usually swam underwater with prey in mouth , apparently with the advantageous result of altering the mouse 's defense from counter @-@ attack to struggling for air . Asphyxiation is the most likely cause of death of endothermic (warm @-@ blooded) prey .

= = = Biomechanical background of tongue projection = = =

Ballistic tongue projection of the related leopard frog is possible due to the presence of elastic structures that allow storage and subsequent release of elastic recoil energy . This is what accounts for the tongue projecting with higher power output that would develop by muscular action alone . Also , such mechanism relieves the tongue ? s musculature from physiological constraints such as limited peak power output - mechanical efficiency and thermal dependence by uncoupling the activation of the depressor mandibulae ? s contractile units from actual muscular movement . In other words , the kinematic parameters developed by contribution of the elastic structures differ from those developed by muscular projection , accounting for the difference in velocity , power output and thermal dependence .

= = Jumping - " Catch Mechanism " = =

= = = Definition = = =

Bullfrogs are able to jump distances ten times their body length thanks to the ability of activating muscular contractile units prior to extension of the plantaris muscle . In this process , sarcomeric contraction generates strain in elastic structures such as tendons , which in turn ? catch ? the

energy generated by the strain . Such is subsequently released as the plantaris actively stretched during jumping , adding to the energy generated by muscular action alone , and thus generating supramaximal powers that will allow the bullfrog to jump great distances . Thus , the catch mechanism relies on elastic structures acting as muscle power amplifiers thanks to their ability of absorbing elastic strain energy and retaining it for later explosive release during jumping .

= = = Advantages = = =

The fact that the catch mechanism relies on elastic structures used as power amplifiers implies a series of conditions much convenient for the bullfrog . Sonomicrometry and electromyographic recordings of the plantaris muscle corroborate a relationship between presence of muscle @-@ tendon units and decreasing , variable gearing . By supplying additional work output through the coupling of elastic strain energy , elastic structures relieve the musculature from the need of shortening at velocities that would otherwise hinder the amount of force generated and thus , the magnitude of power output . This is also aided by a decreasing gearing , which makes it possible for the bullfrog to generate the desired velocity of movement by relieving the plantaris from strennous shortening velocities , achieving the velocity desired by slower , forceful contractions . Like in the case of its ballistic tongue projection , elastic structures in the plantaris muscle also confer it thermal independence . Studies show that jumping peak power output and mechanical efficiency of high elevation frogs of the families Hyla , Eleutherodactylus , Colostethus and Atelopus , which achieve these at temperatures as low as 5oC , are not statistically different from those achieved by tropical Bufo frogs at 35oC .

= = Ecology = =

Bullfrogs are an important item of prey to many birds (especially large herons) , North American river otters (Lontra canadensis) , predatory fish , and occasionally other amphibians . Predators of American bullfrogs once in their adult stages can range from 150 g (5 @.@ 3 oz) belted kingfishers (Megaceryle alcyon) to 1 @,@ 100 pound American alligators (Alligator mississippiensis) . The eggs and larvae are unpalatable to many salamanders and fish , but the high levels of activity of the tadpoles may make them more noticeable to a predator not deterred by their unpleasant taste . Humans hunt bullfogs as game and consume their legs . Adult frogs try to escape by splashing and leaping into deep water . A trapped individual may squawk or emit a piercing scream , which may surprise the attacker sufficiently for the frog to escape . An attack on one bullfrog is likely to alert others in the vicinity to danger and they will all retreat into the safety of deeper water . Bullfrogs may be at least partially resistant to the venom of copperhead (Agkistrodon contortrix) and cottonmouth (Agkistrodon piscivorus) snakes , though these species are known natural predators of bullfrogs as are northern water snakes (Nerodia sipedon) .

= = Human use = =

The American bullfrog provides a food source , especially in the Southern and some areas of the Midwestern United States . The traditional way of hunting them is to paddle or pole silently by canoe or flatboat in ponds or swamps at night ; when the frog 's call is heard , a light is shone at the frog which temporarily inhibits its movement . The frog will not jump into deeper water as long as it is approached slowly and steadily . When close enough , the frog is gigged with a multiple @-@ tined spear and brought into the boat . Bullfrogs can also be stalked on land , by again taking great care not to startle them . In some states , breaking the skin while catching them is illegal , and either grasping gigs or hand capture are used . The only parts normally eaten are the rear legs , which resemble small chicken drumsticks and can be cooked in similar ways .

Commercial bullfrog culture in near @-@ natural enclosed ponds has been attempted , but is fraught with difficulties . Although pelleted feed is available , the frogs will not willingly consume artificial diets , and providing sufficient live prey is challenging . Disease also tends to be a problem

even when great care is taken to provide sanitary conditions . Other challenges to be overcome may be predation , cannibalism , and low water quality . The frogs are large , have powerful leaps , and inevitably escape after which they may wreak havoc among the native frog population . Countries that export bullfrog legs include Belgium , the Netherlands , Mexico , Bangladesh , Japan , China , Taiwan and Indonesia . Most of these frogs are caught from the wild , but some are captive @-@ reared . The United States is a net importer of frog legs .

The American bullfrog is used as a specimen for dissection in many schools across the world . It is the state amphibian of Missouri , Ohio , and Oklahoma .