Rana catesbeiana - American Bullfrog

American Bullfrog

*Rana (Lithobates) catesbeiana*

*(Shaw, 1802)*

---

**TOP 10 BULLFROG FACTS**

1. Bullfrogs can leap up to 10x body length (2 meters)
2. Weigh up to 1 kg
3. Adults can grow up to 18 centimeters in length (excludes legs)
4. Longest lifespan: 16 years in captivity, 10 years in the wild
5. Calls excessively when thunderstorm approaches
6. Food delicacy: Juicy and meaty hind legs
7. Asian dessert: Dried fatty tissues of frog's ovaries have anti-aging properties (Hasma or Oviductus ranae) [2]
8. Major invasive species originating from North America
9. Resistant to lethal amphibian fungal infection (chytridiomycosis) [3]

---

**Introduction**

- Largest frog species in Singapore
- Aquatic frog, belonging to the family 'true frogs' (Ranidae)
- Bulk of *Rana (Lithobates) catesbeiana* population is with the commercial breeding company (Jurong frog farm)
- Reared and exported the frogs as food
• Increase sightings of *Rana (Lithobates) catesbeiana* in Singapore's water catchment areas [5].

**Invasive Species Implications**

**Taxonomy**

• Taxonavigation

• Names
  • Which name do we use?
  • Type information
  • Original description
  • Phylogenetics
  • Gene sequences

• Barcode

• Color

• Legend

• Mitochondrial gene: Cytochrome C Oxidase Subunit 1 (COI)

• Nuclear gene: 18S Ribosomal DNA

---

**Etymology**

The genus name ‘*Rana*’ is a Latinized word meaning frog, is a proposed genus name by George Shaw in 1802 [6]. However in 2006, John S. Frost replaced the genus to ‘*Lithobates*’ [7], which is a combination of two Greek words ‘’ and ‘’. The word ‘’ stands for gemstone, while the word ‘’ stands for walk. The species name ‘*catesbeiana*’ is to honor Mark Catesby who was a famous English naturalist who first discovered the bullfrog. The later revision by Green (2007) of the species name ‘*catesbeianus*’ is a new Latin patronym for Mark Catesby.

---

**Physical Traits**

**Adults**

*Photo taken by Ip Yin Cheong Aden*
**Overall body**

1. Smooth and non-warty skin
2. Absence of dorso-lateral ridges
3. Adult dorsal coloration range from greenish, to yellowish or olive-blackish.
4. Ventral coloration is usually whitish or yellowish accompanied with dark mottling patches.
5. Head usually a lighter shade of green, with its legs being darkly blotched or banded
6. General coloration varies widely according to habitat/location [9]

**Limbs**

1. Long and muscular hind legs
2. Well developed webbing in between the toes of hind feet
3. Anterior limbs are much shorter than the hind legs and are used to prop the frog's posture up tall.
4. No webbing is seen between the fingers of the anterior limbs
5. Both the tips of the frog's fingers and toes are blunt [10]

**Head**

1. Broad snout
2. Small nostrils are situated near the tip of the snout
3. Teeth in its upper jaw
4. Vocal openings at the corner of the mouth [11] Large eardrums (tympanums)
5. Supra-tympanic fold just above the tympanum, starting from the eye and past the eardrum and finally extending towards its anterior limbs.
6. Prominent eyes that are situated above the head unlike the tadpoles which have eyes on the sides of their heads
7. Almond-shaped horizontal pupils and brown irises.

**Diagnosis**

General diagnostic traits for comparison with other frog species:

1. True frog appearance
2. Smooth skin
3. Webbed feet
4. Long hind legs that represent about half its body length and 40% of its body weight.
5. Deep and resonant mating call that resembles the moo of the cow [12] (hence its vernacular name, the American bullfrog.)

![Rana catesbeiana calling in a mating pond](https://example.com/image)

Distinct traits for comparison with closely-related ranid frog species:

1. Large tympanums
2. Prominent supra-tympanic folds
3. Lack of dorso-lateral ridges [13]

This distinctly identifies the American bullfrog (*Rana* (*Lithobates*) *catesbeiana*), which is often mistaken for the river frog (*Rana hecksher*), pig frog (*Rana grylio*) and green frog (*Rana clamitans*) since the geographical ranges of these three species overlap with *Rana* (*Lithobates*) *catesbeiana*’s native range.

*The tympanums are the circular eardrums that are situated right behind each eye of the frog.*

**Sexual Dimorphism**
Summary of sexual dimorphism

<table>
<thead>
<tr>
<th>Trait of comparison</th>
<th>Male Bullfrog</th>
<th>Female Bullfrog</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to reach sexual maturity</td>
<td>1 to 2 years [14]</td>
<td>2 to 3 years [14]</td>
</tr>
<tr>
<td>Average snout to vent length</td>
<td>152 mm</td>
<td>162 mm [15]</td>
</tr>
<tr>
<td>Tympanum size</td>
<td>Twice the size of eye</td>
<td>Same size as eye</td>
</tr>
<tr>
<td>Ventral throat coloration</td>
<td>Yellowish</td>
<td>Whitish</td>
</tr>
<tr>
<td>Pigmented nuptial pads</td>
<td>Present</td>
<td>Absent</td>
</tr>
<tr>
<td>Additional notes</td>
<td>-</td>
<td>Retain some juvenile color and morphology [16]</td>
</tr>
</tbody>
</table>

Juvenile Adults

Juvenile adults or frog-lets are the intermediate transition phase of the metamorphosed tadpoles that have re-absorbed their gills and finned tails. They are miniatures of adult bullfrogs.

- Average 4 cm from snout to vent
• Do not have sexually dimorphic characteristics yet \cite{17}
• Orange irises in their eyes \cite{18}
• Possess a grey oval shaped skin area between their eyes which is called the parietal eye \cite{19}

*The parietal eye is homologous to a third eye and is capable of sensing changes in light intensity related to day and nightfall, which is also used for synchronization of its biological clock (circadian rhythmicity).

**Larvae (Tadpoles)**

• Tadpoles are also very large by frog standards, 8cm to 15cm \cite{20}
• Long, muscular tail with broad dorsal and ventral fins
• Downward-facing mouths
• Dorsal coloration is brown to light olive with small black spots scattered across the head and upper body.
• Ventral side is usually whitish to yellowish in color.
• Initially have three pairs of external gills, and several rows of labial teeth \cite{21}
• Unlike the adult frogs, tadpoles have their eyes at the sides of their heads with orange irises

Tadpoles pump water through their gills by movements of the floor of their mouths, trapping bacteria, protozoans and other small particles on mucus in a filtration organ in their pharynges. As they grow, they begin to ingest larger particles and use their teeth for rasping. Growth of hind legs are usually observed before the anterior limbs bud out while the tadpole metamorphoses into a frog-let \cite{22}

**Eggs**

• Very small
• Dorsal black color
• Slightly lighter or whitish ventral underside
• Each egg is surrounded by a jelly capsule
• Additional jelly that creates a loose cohesion to the entire mass of eggs
• About 10,000 to 20,000 eggs are usually laid near the water surface in one brood \cite{23}

**Biology**

**General behavior** \cite{24}

<table>
<thead>
<tr>
<th>Trait</th>
<th>Adults</th>
<th>Larvae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity</td>
<td>Principally nocturnal, though observed to be active throughout the day</td>
<td>Principally nocturnal, though observed to be active throughout the day</td>
</tr>
<tr>
<td>Residing environment</td>
<td>Semi aquatic and terrestrial</td>
<td>Fully aquatic</td>
</tr>
<tr>
<td>Feeding type</td>
<td>Carnivorous</td>
<td>Herbivorous</td>
</tr>
</tbody>
</table>
Types of defensive behavior

- **Grappling for Defense**

  Mature male *Rana* (*Lithobates*) *catesbeiana* are extremely territorial animals. The male frogs do not hesitate in attacking a competitor or intruder of their turf, with rapid kicking, leaping and grappling.

- **Biting in Defense**

  *Rana* (*Lithobates*) *catesbeiana* have large mouths with a row of teeth in the upper jaw, rendering it capable of inflicting painful bites onto unsuspecting targets. The small teeth on its upper jaw are effective tools to help the bullfrogs to grab it prey as well.

- **Vocalization for Defense**

  *Rana* (*Lithobates*) *catesbeiana* often uses defensive vocalization for self-protection. Their vocal defensive behavior acts to ward off danger to both conspecifics and predators. The defensive call, also known as the distress call, is rapid, unpleasant sounding and piercing for its predator [26].

  Rana catesbeiana distress call <at 0.16 of video>

Mating Behavior

- Males are extremely territorial
- Occupy sites that are usually spaced 3 to 6 meters from the next frog and call loudly [27]
- Males make different types of calls, such as territorial calls to warn other males [28]
- Males make advertisement calls to attract females [29]

*Mating pair of bullfrogs on the right, engaged in the amphiplexus position<Photo taken by Ip Yin Cheong Aden>*

*Males only clasp females in the amphiplexus position, after they have signaled their willingness for mating [30]. This debunks the prior belief that a male frog will opportunistically clasp any nearby female to mate regardless of her consent [31].*
Habitat and Reproductive cycle

*Rana (Lithobates) catesbeiana* can thrive in a wide range of environmental conditions since they are a species of frogs that easily adapt to the environment. They are found in both temperate where they hibernate over winter, as well as tropical regions where temperatures can go up to 40 °C. The duration of the breeding season is influenced by the amount of sunlight, temperature, atmospheric pressure and humidity. The closer *Rana (Lithobates) catesbeiana* is to the equator, the longer its reproductive period through the year. It has been observed that *Rana (Lithobates) catesbeiana* breeds all year round in Singapore, but only have a three-month breeding season in North America.

Once the eggs are laid, the development of embryos is determined by temperature, whereby larvae will hatch within 48 hours in warmer conditions above 26 °C. Egg masses are laid near the water surface for facilitation of oxygen diffusion into eggs. Larvae are about 10mm long, attach to smooth surfaces and consume their yolk sac within 72 hours. After the yolk sac has been emptied, the larvae become free swimming and filter feeding tadpoles.

**Larvae**

- Hatch in about 4 days to be fully aquatic and gilled tadpoles
- Tadpole stage may persist for up to 2 years
- The longer the time taken for a tadpole to metamorphose, the larger the adult would be

The occurrence of metamorphosis in tadpoles depends on two environmental factors which also act as the forces for natural selection:

1. Competitive interaction; includes predator, inter and intraspecific interactions
2. Environmental conditions; food availability, temperature, water quality

*Decreased competitive interactions and more favorable environmental conditions (food, high temperature and clean water), would accelerate the process of metamorphosis from tadpoles to adults.*

**Adults**

- After one or two years, tadpoles metamorphose into adults
- Reproduction occurs in permanent water bodies (In Singapore since its warm all year round, breeding season is all year, especially after episodes of heavy rainfall)
- Males attract females by calling (a deep, hoarse "ba-rum" or "jug-o-rum")

**Rana (Lithobates) catesbeiana calling and mating**

- Mating occurs in water; males clasp females and hold them in amphiplexus
- Females release eggs while in amphiplexus; eggs are surrounded by a gelatinous sheet that adheres to vegetation
- Fertilization is external
- Average lifespan of adults is about 6 years

**Diet**

- Adults usually ambush its unsuspecting prey by sitting quietly
- As the prey passes by, it lunges forward with a wide open mouth, powered by its powerful hind legs.
- The bullfrog eats and swallows practically anything that can fit into their mouths.
- They have a wide range of prey, from insects to mice, fish, birds, herpetofauna (snakes and turtles) and even its own kind (cannibalism).

*American bullfrogs eat anything that fits into its mouth!*

- Bullfrog tadpoles mostly graze on aquatic plants, or eat suspended matter, organic debris, algae, plant tissue, and small aquatic invertebrates
- During metamorphosis, diet gradually shift towards ingesting animal protein
- Fully carnivorous after tail resorption in the froglets
- A day in the life of a bullfrog tadpole
Distribution

Global

*Adapted from CABI; direct permission not obtained, but within limits of Fair Use [39]

Singapore
American bullfrogs sighted in Singapore water catchment with corresponding number labels of reservoirs (Author’s modification from Google Maps)

Click here to access interactive Google Map for local American Bullfrog Sightings.

The objective of this map is to allow the general public to mark out the places where they have spotted the American bullfrogs in Singapore. This would aid in monitoring and assessment of the spread of this invasive frog species with respect to local ecosystems, native anuran species richness and ecological balance.

The American bullfrog is locally found in the water catchment areas as well as drains, canals and park connectors [40]

Sighted in:

1. Macritchie Central Catchment (Most sighted)
2. Seletar reservoir
3. Peirce reservoir
4. Pandan reservoir
5. Punggol reservoir
6. Marina reservoir
7. Kranji reservoir
8. Jurong lake
9. Bedok reservoir

Invasive Species Implications
Frog farm containment walls are only as high as 1 meter; bullfrogs may escape by leaping over walls <Photo taken by Ip Yin Cheong Aden>

- Imported into Singapore since American bullfrog legs are a profitable and marketable consumable food commodity
- Easily cultivated but also difficult to contain as they are very prone to escaping (leaps up to 2 meters)
- Used in aquatic pet trade as baits or food for the Arowana fish (F. Osteoglossidae)
- Accidental release or escapes result in thriving populations with thousands of bullfrogs within a year of colonization arising from just one successful spawning event [41].
An escaped or released American bullfrog spotted in one of the local waterways <Photo taken by Ip Yin Cheong Aden>

- They are highly adaptable to new environments and are large, opportunistic predators that out-compete native anurans.
- Larvae rapidly eat algae especially in nutrient poor ponds, monopolizing primary production and upset aquatic community structure.
- The American Bullfrog is resistant to Chytridiomycosis and hence is a well known vector for transmitting this deadly amphibian disease.
- The chytrid fungus, *Batraochytrium dendrobatidis*, causes the disease that has wiped out many anuran species thus far.
- Listed as the top 100 most devastating invasive species by the Global Invasive Species Database.
- DO NOT release your pet American bullfrogs, prevent the bullfrog baits and commercially farmed frogs from escaping into our local ecosystem!

**Taxonomy**

**Taxonavigation**

- Domain: Eukaryota
- Kingdom: Metazoa
- Phylum: Chordata
- Subphylum: Vertebrata
- Class: Amphibia
- Order: Anura
- Family: Ranidae
- Genus: *Rana* (Shaw, 1802)
- Sub-Genus: *Lithobates* (Frost et al., 2006)
- Species: *Rana catesbeiana* (Shaw, 1802) [47]
- Species (Revised and Preferred): *Lithobates catesbeianus* (Green, 2007) [48]

**Names**

- Binomial: *Rana catesbeiana* (Shaw, 1802) [50]
- Vernacular: American bullfrog, Common bullfrog, Edible bullfrog, Eastern bullfrog, Jug-'O'-rum, Bloody nouns
- Synonyms:
  - *Rana catesbeiana, Rana (Lithobates) catesbeiana* (Shaw, 1802) [51]
  - *Rana (Rana) catesbeiana* (Boulenger, 1920; Dubois, 1978)
  - *Rana catesbyana* (Smith, 1978)
  - *Rana (Aquarana) catesbeiana* (Dubois, 1992)
  - *Rana (Novirana, Aquarana) catesbeiana* (Hillis and Wilcox, 2005) [52]
  - *Lithobates catesbeianus* (Frost et al., 2006) [53]
  - *Lithobates (Aquarana) catesbeianus* (Dubois, 2006)

**Which name do we use?**

This frog species was shifted by [54] into the genus *Lithobates* based on extensive sequence data, which is highly debatable because if *Lithobates catesbeianus* was used, a lot of literature on *Rana catesbeiana* prior to this name change would be lost. Hence, Hillis and Wilcox (2005) [55] proposed *Lithobates* as a subgenus, whereby it is used in a different sense for smaller group of species. Although notable organizations such as the International Union for Conservation of Nature (IUCN), Encyclopedia of Life (EOL) and Animals and Plants of Singapore (APS, LKCNHM) use either *Lithobates catesbeianus* or *Rana catesbeiana*. The Centre for Agricultural and Biosciences International (CABI) also advised to use *Lithobates* as a subgenus and this frog’s name could be expressed as *Rana (Lithobates) catesbeiana*. This would thus maintain and preserve the long historical build up of information on phylogeny and taxonomy of *Rana (Lithobates) catesbeiana*.

**Type information**

George Shaw (1802) is an English naturalist who gave this bullfrog its original name *Rana catesbeiana* [57]. He gave the type locality (*R. catesbeiana*) as “North America”, although that was later restricted to “vicinity of South Carolina”, Charleston by Schmidt (1953). A type specimen is not known to exist. The collector and date of collection are unknown [58].

*Present holotype locality status: Unknown

**Original description**

Size very large (maximum SVL 203mm in females). Dorsum green to almost black, or with net-like pattern of gray or brown on green ground; venter whitish, mottled gray (at times), and with a yellowish wash, especially on the throat of males; no dorso-lateral ridges; feet with tip of fourth toe extending beyond web; digital disks absent. 

Bull Frog.

Catory this species has been described by Kain, and other travelers. It is said to indicate the approach of rain by its piping voice, during the spring and beginning of summer. The ears in the living animal have a bright golden ring, or metallic gleam. A frog much allied to the above, and perhaps a variety, is described and figured by Sela, vol. ii. p. 37, t. 37; but it is said to be a native of Africa.

Bull Frog.

Rana Catesbeiana. R. ferox—Reese's marbled agama marina, and the same species, but darker in color, with large oval spots, and a paler foot. The Bull Frog. Const. Cor. p. 25, pl. 30.

This remarkable species is not uncommon in many parts of North America, where it is known by the name of the Bull Frog, its voice resembling the distant lowing of that animal. It grows to a very large size, the individual represented by Mr. Catesby, in his Natural History of Carolina, and which he assumes was taken from a small rather than a large specimen, seeming to measure about eighteen inches from the nose to the end of the hind foot. Its colour, on the upper parts, is a dusky olive, or brownish, somewhat irregularly marked with numerous deep-brown spots; while the under parts are of a pale or whitish cast, with a tincture of yellowish green, and marked with numerous spots, but much less vivid or distinct than those of the upper parts. The fore feet have only four toes, and are unwebbed, but the hind feet, which are large and long, have five toes, and are very widely webbed or palmarized. The irides of the eyes are red, surrounded with a narrow border, or secondary iris, as it were, of yellow. The ears, or rather the external membranous of those organs, are large, round, of a brownish red colour, surrounded by a well-defined pale or yellowish white margin.

Mr. Catesby tells us that the Bull Frog is less numerous in North America than any other kind; that it frequents springs only, which in Virginia abound in the sides of every little hill, where by the continual running of the water a small pool or hole is usually made before the mouth of the spring, which is rarely without a pair of these frogs, which are usually seen sitting on the verge of the hole, and when surprised, with a long leap or two, enter the mouth of the spring, where they are secure. He adds, that it is the common belief of the people in Virginia that they keep the springs clean, and purify the water, and therefore the general prejudice is in their favour; though, on account of their being great devourers of young ducks and geese, which they often swallow whole, they are sometimes destroyed.

It does not appear that Linnaeus has distinctly described this species, unless we suppose him to have really intended it by his Rana ocellata. If this be the case, we must admit, that by some very extraordinary inaccuracy, he has confounded two widely different species together, in which he appears to have been followed by the Count de Cepeda. In the Gmelinian edition of the Systema Nature the trivial name of ocellata is retained.
Phylogenetics

A phylogenetic study of Amphibia by Pyron and Weins (2011) has conducted a maximum likelihood analysis on Amphibia phylogeny based on 12,871 base-pairs of sequence data from the concatenation of 12 genes (9 nuclear, 3 mitochondrial), covering both higher and lower taxonomic levels (up to 2800 amphibian species).

9 nuclear genes:

1. C-X-C chemokine receptor type 4 (CXCR4)
2. Histone 3a (H3A)
3. Sodium–calcium exchanger (NCX1)
4. Pro-opiomelanocortin (POMC)
5. Recombination-activating gene 1 (RAG1)
6. Rhodopsin (RHOD)
7. Seventh-in-absentia (SIA)
8. Solute-carrier family 8 (SLC8A3)
9. Tyrosinase (TYR)

3 mitochondrial genes:

1. Cytochrome b (cyt-b)
2. Mitochondrial ribosomal subunit 16S
3. Mitochondrial ribosomal subunit 12S
The placement of *Rana* (*Lithobates*) *catesbeiana* on the amphibia phylogenetic tree is represented in the 3 figures below. The figures are presented in a chronological order that goes down the Taxonomic hierarchy. Starting from the Class, Order, Superfamily and Family [Fig. 1]; proceeding on to Family and Genus level [Fig. 2]; and lastly down to Genus and Species level [Fig. 3].

Bootstrap values for maximum likelihood have been indicated on the tree branching nodes for all 3 figures below. (Adapted from Science Direct; direct permission not obtained, but within limits of Fair Use)

![Diagram](image_url)

Figure 1. Skeletal representation of the maximum likelihood analysis of the concatenated 12 genes of the Orders, Superfamilies and Families in the Class Amphibia.

Moving down the taxonomic hierarchy, the right vertical lines denote the 3 Orders, while the node bases denote the superfamily and line tips represent family. *Rana catesbeiana* is in the Order Anura, Superfamily Ranoidae and Family Ranidae as boxed in red. Bootstrap values are indicated at the branch nodes.
Figure 2. Family Ranidae phylogeny’s maximum likelihood estimate based on concatenated sequencing data of 12 genes (expanded from Fig. 1).

*Rana catesbeiana* (American bullfrog) isolated in red is seen to be in the same clade as 7 other Ranoid frog species. This includes the 3 closely related true frogs (annotated with red arrows) namely the *R. clamitans* (Green frog), *R. grylio* (Pig frog) and *R. heckscheri* (River frog), which share the same native geographical range and often mis-identified as *R. catesbeiana* by para-taxonomists. Bootstrap values are indicated at the branch nodes.

*Compare misidentified Ranoid true frogs*

**Gene sequences**

The study by Pyron and Wiens (2011) did not utilize the mainstream barcoding genes like mitochondrial gene (COI) or nuclear gene (18S rDNA) for taxonomic delineation. However, most barcoding data for species delineation published on GenBank commonly involves COI or 18S rDNA. Hence, the following mainstream barcode data has been provided to serve as a linking platform to the respective databases for researchers working on barcoding projects (e.g. eDNA water testing studies that involve *Rana* (*Lithobates*) *catesbeiana*).

The illustrative barcode represents a fragment of DNA sequences, with each base uniquely colored for a rough visual identification of the nucleotide composition makeup of the gene.
**Barcode Color Legend**

<table>
<thead>
<tr>
<th>Nucleotide</th>
<th>Color Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adenine (A)</td>
<td>Green</td>
</tr>
<tr>
<td>Thymine (T)</td>
<td>Red</td>
</tr>
<tr>
<td>Guanine (G)</td>
<td>Black</td>
</tr>
<tr>
<td>Cytosine (C)</td>
<td>Blue</td>
</tr>
</tbody>
</table>

**Mitochondrial gene: Cytochrome C Oxidase Subunit 1 (COI)**

[Barcode illustration]

Illustrative COI barcode (646bp) for *Rana catesbeiana* obtained from BOLD systems that was deposited in NCBI GenBank. COI sequence file (.fasta) can be obtained from GenBank.

**Nuclear gene: 18S Ribosomal DNA**

[Barcode illustration]

Illustrative 18S rDNA barcode (581bp) for *Rana catesbeiana* obtained from BOLD systems. 18S sequences can be obtained from BOLD systems.

*Back to top

**References**


60. Conant, R. (1958). A field guide to reptiles and amphibians of the United States and Canada east of the 100th meridian. Smith II


This page was authored by Ip Yin Cheong Aden

Last curated in 2015