

**An Evaluation of a Bullfrog Population at a
Housing Development know as, *Enchantment at
Hightstown*: the Problems they Cause
and Some Possible Remedies**



An adult female American Bullfrog (*Lithobates [Rana] catesbeiana*).

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To

Mr. and Mrs. E. Martin Davidoff

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By

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INTRODUCTION

Mr. and Mrs. Davidoff, who reside at a housing development known as: *Enchantment at Hightstown* contacted me to help them with a problem they are having with noisy Bullfrogs (*Lithobates* [*Rana*] *catesbeiana*). Hightstown is located near several major roads including Routes 133, 539 and 571, and is adjacent to Exit 8 of the New Jersey Turnpike in East Windsor. *Enchantment at Hightstown* is an elegant 55+ adult community in Mercer County, New Jersey. This adult community offers single family homes with 2 and 3 bedrooms with a square foot range of 1,524 to 2,700. *Enchantment at Hightstown* was built between 2006 and 2010 by the award-winning developer, the Robertson - Douglas Group. It is currently managed by a Homeowner's Association. As part of the engineering plans for the construction of the project, several water detention and retention basins were built for the drainage collection of rain water runoff. Water detention basins allow rainwater to percolate down into the soil and do not hold surface water very long. In other words, they dry up. However, retention basins are designed to hold water indefinitely. Two of these retention basins are in the close proximity to several residents' homes (**Figures 1 and 2**). These are water retention basins 6 and 7, which permanently hold water year round and thus can attract highly aquatic wildlife, including frogs.

THE PROBLEM

What residents of *Enchantment at Hightstown* did not know when they purchased their homes was that they would be serenaded over a three to four month period each year by the vocal breeding calls of male Bullfrogs during the day, and even louder and more intensive at night. The breeding season for Bullfrogs begins in mid-May and continues through early August. Adult Bullfrogs gather at breeding ponds in late spring and early summer, which is later than most other native frog species. Males stake out territories along the edge of a pond and defend the site. They float in the water and call loudly to attract pregnant females, but chase away other rival males. Under normal conditions in some wetland habitats, Bullfrog populations are low because of natural competition and an abundance of snake, turtle, bird and mammal predators who eat their tadpoles, juveniles and adult frogs (Calhoun and Klemens, 2002). It's on the contrary at *Enchantment at Hightstown*, where retention ponds 6 and 7 do not have an abundance of predators (**Figure 3**). Instead, this population of Bullfrogs has grown to a maximum carrying capacity, which is the largest density of Bullfrogs that I have ever seen in my 50-years as a professional herpetologist (Zappalorti, personal observation).

HOW DID THE BULLFROGS GET THERE

There are a number of natural streams and lakes in the East Windsor and Hightstown region of Mercer County. The closest water bodies to *Enchantment at Hightstown* are Peddie Lake which is 1,575-feet to the southwest. Likewise there is a major stream corridor 2,000-feet to the northeast of *Enchantment at Hightstown*, that is separated by Route 133. Adult Bullfrogs are capable of traveling great distances overland at night, especially during rain. They can hop across roads and move through woodlands and grassy meadows to reach other water bodies where they can take-up residence. As more and more Bullfrogs of both sexes found their way to retention ponds 6 and 7, a population was established. Without any predators, the population has increased drastically.



Figure 1. A southwestern view of retention pond 6.



Figure 2. A western view of retention pond 7.

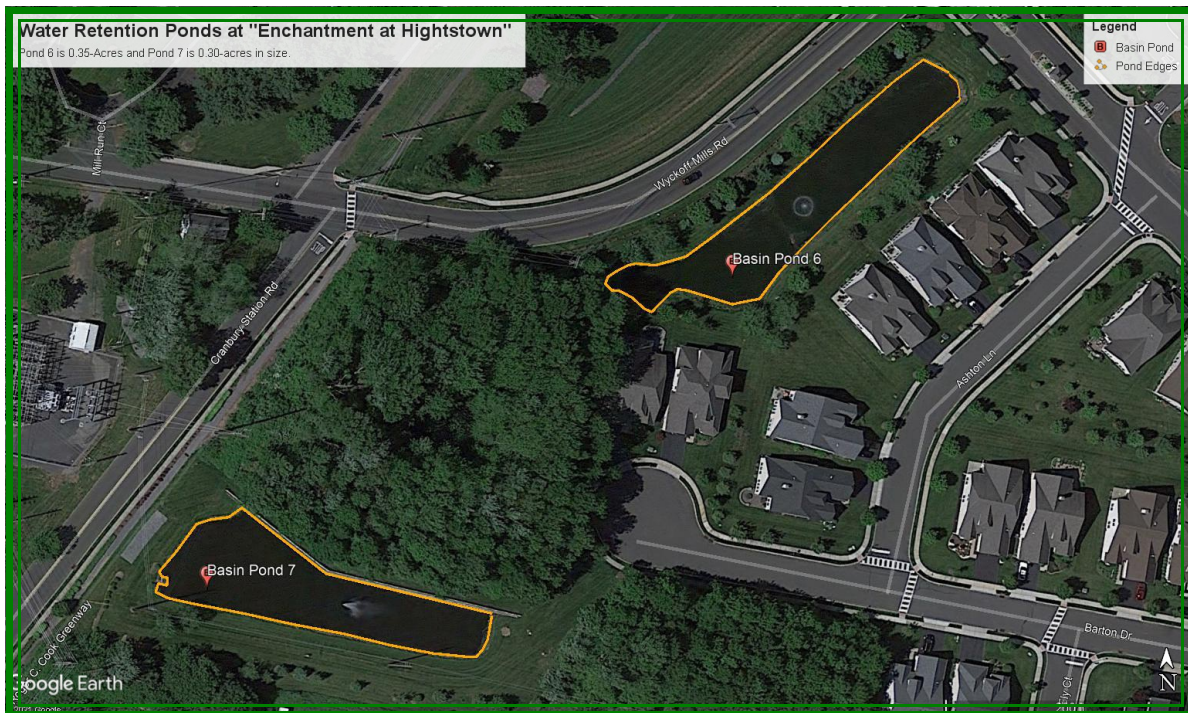


Figure 3. A Google Earth map showing the location of basin ponds 6 and 7. Notice how close basin pond 6 is to several of the homes. Frogs can move from one pond to the other during the night.

THE BULLFROG’S LIFE HISTORY

In order for the average person to better understand why Bullfrogs have become well established at *Enchantment at Hightstown*’s retention ponds 6 and 7, one must know the frog’s complete life history. The Bullfrog’s ecology and natural history are provided herewith.

The American Bullfrog was formally scientifically known as *Rana catesbeiana*, and is often simply referred to as the common Bullfrog in Canada and the United States. Scientists refer to this large species as being among the “true frogs” which are native to eastern North America. It typically inhabits large permanent water bodies such as swamps, ponds, lakes, streams and rivers. Bullfrogs can also be found in human made habitats such as Koi ponds, canals, ditches, culverts and retention basins. The Bullfrog gets its common name from the sound the male makes during the breeding season. The vocal call sounds similar to an adult bull bellowing. Because the Bullfrog grows so large, it is commonly eaten throughout its range, especially in the southern United States.

DESCRIPTION

The upper surface of the Bullfrog is olive-green in color, either plain or with mottling or banding of brown. The under surface is white blotched with yellow or gray. Often, a marked contrast in color is seen between the green upper lip and the pale lower lip. The teeth are tiny but useful when grasping prey. The eyes are prominent with brown irises and horizontal, almond-shaped pupils.

The tympanum (eardrum) are easily seen just behind the eyes and the dorsolateral folds of skin encircle the eardrum. The limbs are blotched or banded with black or dark gray. The fore legs 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 (Martof et al., 1980; Duellman and Trueb, 1986).

Bullfrogs are sexually dimorphic, with males being smaller than females and having yellow throats. Males have ear drums (tympanum) that are larger than their eyes, whereas the tympanum in females are about the same size as the eyes (Conant and Collins 1998). Bullfrogs measure about 3.6 to 6 in (9 to 15 cm) in snout-to-vent length. They grow fast in the first eight months of life, typically increasing in weight from 5 to 175 grams (0.18 to 6.17 oz), and large, mature individuals can weigh up to 500 grams (1.1 lbs.). In some cases Bullfrogs have been recorded as attaining 800 grams (1.8 lbs.) and measuring up to 8 in (20 cm) from snout to vent. The Bullfrog grows to be the largest frog in North America (Conant and Collins 1998).



Figure 4. An adult male Bullfrog being held for the photo. Notice the eardrum, which is larger than the eye.



Figure 5. An adult female Bullfrog. The eyes are the same size as their eardrums.

Bullfrogs are typically green or greenish brown, and can be a light or dark shade. The back and sides may be plain or may have dark spots. The arms and legs are spotted or barred with dark blotches. Underparts are white, distinctly or obscurely spotted and mottled. The throat of the male may be yellow. The iris of the eye is either golden or reddish bronze (**Figures 4 and 5**).

RANGE AND PREFERRED HABITAT

Bullfrogs range naturally from the eastern to central United States, north to Nova Scotia, and south to Mexico. This highly aquatic frog prefers still, shallow waters, like those found at the edges of lakes and ponds or sluggish portions of streams and rivers. The bullfrog's natural range extends from Nova Scotia south to central Florida, from the Atlantic coast west to Wisconsin, and across the Great Plains to the Rockies (Conant and Collins 1998).

Their presence as a food source has led to Bullfrogs being distributed around the world outside of their native range. Bullfrogs have been introduced into the Western United States, Canada, Mexico, Central America, South America, Western Europe, China, Taiwan, Japan, South Korea, and southeast Asia (Currie and Bellis, 1969). In these places they are invasive species due to their voracious appetite and the large number of eggs they produce, having a negative effect on native amphibians and other fauna. Bullfrogs are very skittish which makes them difficult to capture and so they often become established in other countries. Albino Bullfrogs are sometimes kept as pets, and Bullfrog tadpoles are often sold at pond or fish supply stores.

BEHAVIOR

Bullfrogs live in freshwater ponds, lakes, canals, ditches and marshes. Bullfrogs like warm weather, but when it turns cold in winter they dig down into mud to hibernate. When active adult Bullfrogs can generally leap about 1 meter (3 feet) in distance in a single bound. Large adults are sometimes capable of jumping 2 meters (6 feet), or ten times their body length without difficulty. Behaviorally, males can be territorial and aggressive. They can sometimes be seen wrestling or having a pushing match with other males. During the cold winter season, Bullfrogs hibernate in mud and litter at the bottom of ponds, lakes or the slow-moving portions of streams and rivers. Maximum lifespan in the wild is estimated to be 8 to 10 years, but one Bullfrog lived for almost 16 years in captivity.

PREDATORS

Bullfrogs have a wide variety of predators that feed on their gelatinous eggs, tadpoles, juveniles and adults. These include aquatic insects (large diving beetles), crayfish, various fishes (especially large mouth bass), other Bullfrogs, aquatic turtles, snakes, wading birds (herons), mammals, and humans who hunt the adults for the food market. When there are few or no predators their populations can increase very quickly, as is the case in retention basin ponds 6 and 7 at *Enchantment at Hightstown*.



Figure 6. A Great Blue Heron eating a Bullfrog.

DIET AND TYPES OF PREY

Bullfrogs are voracious, opportunistic, ambush predators that prey on any small animal they can overpower and stuff down their throats. Bullfrogs are carnivorous, ambush predators and will eat almost any animal they can capture and swallow. Included in their diet are: worms, insects, crayfish, fishes, other frogs, snakes, small turtles, small mammals and even birds when they come to the water's edge for a drink. Bullfrogs eat all kinds of insects, mice, snakes, fish, and other small creatures. They hunt during the day as well as at night. They are sit and wait predators, waiting patiently until they see something pass by that make a good meal. They attack with a powerful leap, lunging at their prey with their mouths wide open. Gulp! Down the gullet the unlucky prey item goes. They will eat other smaller frog species such as green frog (*Lithobates clamitans*), leopard frog (*L. pipiens*) and wood frog (*L. sylvaticus*). They also eat crayfish, water beetles, snails and dragonfly larvae. They will take fish, small turtles, young water birds, and even their own species. They are cannibalistic (Martof et al., 1980).



Figure 7. A Bullfrog eating an Eastern Ribbon Snake.

Motion of an insect, amphibian, reptile, bird or small mammal is what triggers a Bullfrog to attack. In other words, the moving prey elicits feeding behavior. First, 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



Figure 8. An adult male Bullfrog eating a small Bullfrog. They are cannibalistic and will consume smaller frogs that share their habitat.

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 warm-blooded prey.



Figure 9. An adult female Bullfrog eating a Goldfish. Bullfrogs will attack any other animal that they can fit in their mouth and swallow.

Bullfrogs are abundant in their native habitat, playing a role in insect control and energy transfer in the ecosystem. In places like California and Arizona, where Bullfrogs do not occur naturally, but have been introduced by humans, their populations are skyrocketing. Native populations of western frog species are in decline due to competition for resources and predation. As a result, some of those native frog species are being driven toward extinction. Bullfrogs are predators that eat practically anything they can catch (Willis et al., 1956; Currie and Bellis, 1969). They can swallow tree frogs, other amphibians and reptiles such as the western pond turtle, minnows, small birds, and young snakes. Introduced Bullfrogs have been blamed for native species declines in much of the Americas.

REASONS FOR FROG VOCAL CALLS

The baritone call of the bullfrog is so deep and resonant, it resembles the mooing of a bull cow. Only males emit a loud bellowing sound from breeding ponds. When several males are calling, their choruses can be heard up to 300-feet during the day or night. Like most frogs and toads, male Bullfrogs make vocal calls to attract pregnant females. In other words, females will come to the calling male with the most appealing voice. That's why when one male begins to call, all other males within audible distance will join in with their own mating calls (Capranica, 1965). Male Bullfrogs emit a deep base-like bellow which sounds like: "jug-a-rum, jug-a-rum, jug-a-rum." Some people think it sounds like a male cow grunting or mooing, which is why the word "bull" is in its name. The mating call is repeated several times. Sometimes another male will come in contact with the calling male. The intruder will be pushed away by the calling male as it makes a loud warning or grunting sound which tells the intruder he has ventured too close to another males territory.

Males produce loud calls to attract females and establish their territories. They are aggressive when defending their territory. 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 (Bee, 2001; Bee and Gerhardt, 2001). 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 (Howard, 1978; Davis, 1987 and 1988).



Figure 10. Three adult male Bullfrogs calling along the edge of retention basin 6.

REPRODUCTION, GROWTH AND DEVELOPMENT

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. Males only clasp females after they have indicated their willingness to mate. These male and female behaviors will cause male-to-male competition to be high within the Bullfrog population and sexual selection for the females to be an intense process. Males congregate to attract females, and the females arrive to the site for the purpose of copulation (Berroneau et al., 2007).



Figure 11. An adult male Bullfrog calling from the edge of retention basin pond 6. They inflate their lungs with air before calling.

In a 1980 study on Bullfrogs in New Jersey, the mating system was classified as resource-defense polygyny (Ryan, 1980). The males defended territories within the group and demonstrated typical physical forms of defense. Male Bullfrogs aggregate into groups called choruses (**Figures 10 and 11**). 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 (Ryan, 1980).

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 (Megela-Simmons, 1984; Ficetola et al., 2007).

A review of multiple studies on Bullfrogs and other anurans noted male behavior within the groups changes according to the population density. 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 (Emlen, 1968).

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 (Wiewandt, 1969; Wilson, 1995).



Figure 12. A northeastern view of the shore of retention basin 6. Five Bullfrogs can be seen resting at the waters edge.



Figure 13. The gelatinous egg mass of the Bullfrog attached to aquatic vegetation in the water. A single large female can produce between 10,000 and 20,000 eggs during the breeding season.

Adult Bullfrogs gather at breeding ponds in late spring and early summer, much later than most native frog species. Males stake out territories with good egg-laying sites and defend them, calling loudly to attract females and chasing away rival males. After selecting a male, the female deposits eggs in his territory. During the mating grasp (known as 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 her eggs, while the male simultaneously releases sperm, resulting in external fertilization (Schroeder and Baskett, 1968; Duellman and Trueb, 1986; Wassersug, 1997).

The eggs form a thin, floating sheet which may cover a circular area of 8 to 12 inches. 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 can occur. If the temperature falls below 15 °C (59 °F), normal development ceases. While in amplexus (mating), females can lay between 10,000 to 20,000 eggs on the water's surface (**Figure 13**). The Bullfrog eggs hatch in four or five days (depending on water surface temperature). Tadpoles hatch out in July and remain in the ponds through that summer and the following winter, metamorphosing in July, August or September of their second or third year (Durham and Bennett, 1963; Kupferberg, 1997; Stinner et al., 1994).



Figure 14. The larvae or tadpole of a Bullfrog. They take up to two years to metamorphous into small frogs after spending the winter in the pond.

Egg masses are black on top and white underneath. They start as a round, basketball-size gelatinous mass that flattens on the water surface over time (**Figure 13**). In the warmer southern part of a Bullfrog’s range, metamorphosis can take as few as 79 days. However, in New Jersey in the colder northern part of their range, tadpoles may take two or three years to metamorphous. In other words the tadpoles remain in the water during the gill bearing aquatic stage in the winter. Tadpoles are dark green with black dots, have orange or bronze eyes and opaque yellow underbellies, and are up to 6 inches long. After metamorphosis, juveniles are green to brown with small black spots, orange or bronze eyes, and a fold of skin from the eye around the eardrum. Newly hatched tadpoles show a preference for living in shallow water sandy bottoms. This may reflect a lesser number of predators in these locations (Cecil and Just, 1979; Provenzano and Boone, 2009). 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 pharynges. After a few weeks they begin to ingest larger particles and use their teeth for rasping. They have downward-facing mouths, large bodies, and tails with broad dorsal and ventral fins. Metamorphosis ranges from a few months in the warmer southern part of the range up to 3 years in the north, where the colder water slows development. In New Jersey they only stay in the water for one winter and metamorphose the following summer (**Figure 14**).



Figure 15. A northeastern view of retention pond 6. Notice how close the houses are to the pond.

SURVEY METHODS

One objective of this investigation was to make an estimation of the total population size of Bullfrogs living in the two water retention ponds at *Enchantment at Hightstown*. The second objective was to evaluate the situation and make recommendations on how to reduce the size of the Bullfrog population causing disturbance to residents. A habitat evaluation and Bullfrog population estimate was made on the evening and night of June 18, 2021. In order to estimate the Bullfrog population within retention ponds 6 and 7, each individual frog observed was counted from along the shore of the ponds (see **Figures 11 and 12**).

The survey started at 7:00 PM at retention pond 6 and continued after dark at both retention ponds 6 and 7, through 10:30 P.M. I was looking for adult males and females, sub-adult frogs, new metamorph frogs, tadpoles and egg masses. The perimeter of the ponds was slowly walked. A strong flashlight was used to scan the water's edge and to look out into the center of the pond. Bullfrogs typically call while floating on aquatic vegetation from within one or two meters from the pond edge, so calling frogs were easy to see with the aid of a flashlight. It should be noted that the frog's eyes shine from the reflection of the flashlight which makes them easy to spot.

Adult males and females were seen resting on land within 0.5 to 1 meter from the water’s edge, while some were resting as far as 3 meters away from the shore of the ponds. Each individual Bullfrog seen was counted, while being careful not to count the same frog twice. Photos were taken of some of the frogs that would remain sedentary long enough for a picture (**Figures 10, 11, and 12**).

A second pass was made around the two ponds in order to look for egg masses or to count tadpoles. It should be noted that counting tadpoles was difficult because some were in deeper water, which obscured my vision and many were partially hidden on the floor of the pond or in aquatic vegetation. I only included in my count the ones that could clearly be seen. It took approximately one half hour to walk around the retention basin pond for each of the four surveys (e.g., two passes at pond 6 and two passes at pond 7). The survey and Bullfrog population estimate ended at 10:30 PM.

RESULTS

Retention Pond 6 - The water surface size of basin pond 6 is approximately 0.35-acres. A survey and Bullfrog count was made on June 18, 2021. The objective was to look for and count adult males, adult females, sub-adult frogs, new metamorph frogs and tadpoles. The number of individuals observed was:

Adult male Bullfrogs =	66
Adult Female Bullfrogs =	60
Sub-adult Bullfrogs =	13
Metamorph Bullfrogs =	8
Bullfrog Tadpoles =	956

Population estimate = 1,103

Retention Pond 7 - The water surface coverage or size of basin pond 7 is approximately 0.30-acres. A survey and Bullfrog count was made on the evening of June 18, 2021. The objective was to look for and count adult males, adult females, sub-adult frogs, new metamorph frogs and tadpoles. The number of individuals observed was:

Adult male Bullfrogs =	46
Adult Female Bullfrogs =	50
Sub-adult Bullfrogs =	4
Metamorph Bullfrogs =	6
Bullfrog Tadpoles =	851

Population estimate = 957

The combined total number of Bullfrogs living and breeding in both retention pond 6 and 7 are:

Adult male Bullfrogs =	112
Adult Female Bullfrogs =	110
Sub-adult Bullfrogs =	17
Metamorph Bullfrogs =	14
Bullfrog Tadpoles =	1,807

Population estimate = 2,060 = the total estimated population size.

Adverse Impacts

In general, adult American Bullfrogs have voracious appetites and will eat anything they can fit into their mouths, including invertebrates, birds, bats, rodents, frogs, newts, lizards, snakes, and turtles. Bullfrog tadpoles mainly eat algae, aquatic plant material, and invertebrates, but they will also eat the dead tadpoles of other frog species. As a result of these feeding behaviors, all lifestages of Bullfrogs prey upon and are able to out-compete native frogs and other aquatic species. Additionally, Bullfrogs are a known carrier of *chytrid* fungus, which causes the potentially fatal skin disease in frogs called *chytridiomycosis*. *Chytridiomycosis* is believed to be a leading cause of the decline of native amphibian populations all over the world and responsible for the extinction of over 100 species since the 1970s. However, it should be strongly noted that the Bullfrog population at *Enchantment at Hightstown* is in good health and show no sign of infection by the *chytrid* fungus.

These finding indicate that the noise from 40 or 50 adult male Bullfrogs calling for several hours each day or night is so loud that the sound penetrates the exterior and interior of close-by homes. The Bullfrogs' ongoing sounds result in disturbing and disquieting levels of annoying noise which dominates the personal space of the residents. Furthermore, due to density of the Bullfrogs in retention ponds 6 and 7, the male breeding calls become even louder and more intensive throughout the night. The high frog volume coincides with the time when residents retire for the night. Therefore, it is reasonable to determine that the level of noise from the vocal calls of the frogs can be heard through their bedroom windows when they are trying to sleep. Bullfrog sounds not only penetrate into a resident's bedroom, but at times it is so loud and distressing that it prevents and adversely impacts the resident's sleep. The breeding calls of the Bullfrogs start with intensity at dusk and continue throughout the night at various levels.

MEASURING AUDIBLE NOISE LEVELS FROM BULLFROGS

Ostergaard Acoustical Associates (1460 US Highway 9, Woodbridge, New Jersey 07095), was commissioned by Mr. and Mrs. Davidoff, to measure the level of noise produced by the combined vocal calls of the Bullfrog population. Ostergaard Acoustical Associates made recording measurements of frog noise on the patio at 9 Ashton Lane and at 25 Barton Drive. Measurements were made with a Bruel & Kjaer random-incidence condenser microphone 4189, used in conjunction

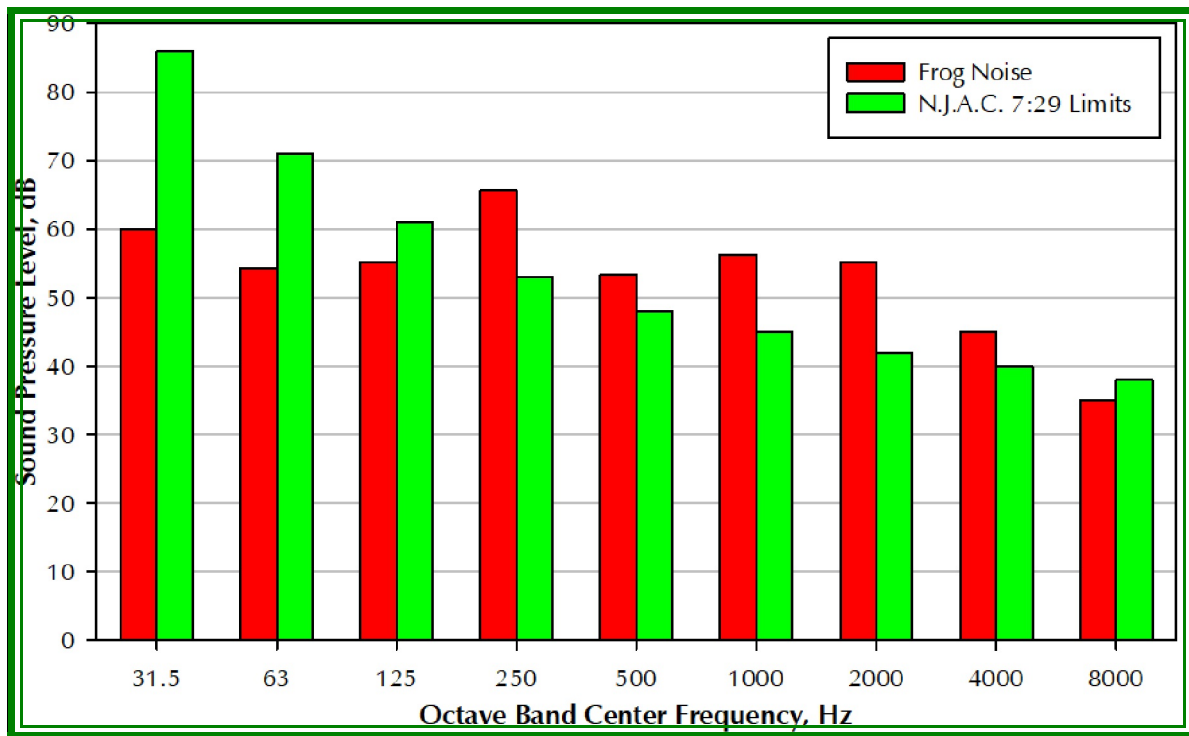


Figure 16. Comparison of maximum frog noise spectrum to N.J.A.C. 7:29 limits for residential receivers during nighttime hours between 2200 and 0700. (Source: Ostergaard Acoustical Associates).

with a preamplifier, Bruel & Kjaer Model ZC 0032, and a precision sound level meter and octave band analyzer, Bruel & Kjaer Model 2250. A windscreen was used on the microphone to reduce wind noise. The entire system was calibrated before and after the measurements by means of a sound pressure level calibrator with calibration traceable to the National Institute of Standards and Technology (see **Figures 16, 17 and 18**).

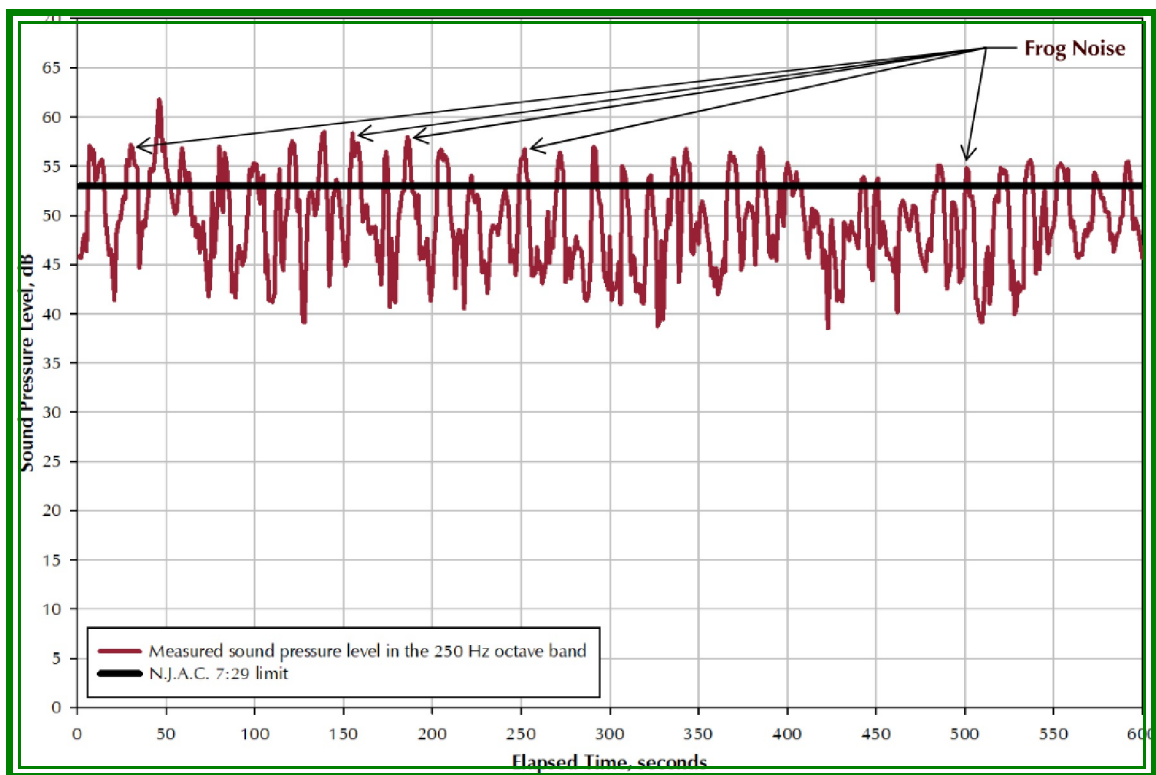


Figure 17. Time history in 250 Hz octave band for first measurement at 9 Ashton Lane between 2154 and 2204 hours, compared with N.J.A.C. 7:29 limit for residential receivers during nighttime (2200-to-0700) hours. (Source: Ostergaard Acoustical Associates).

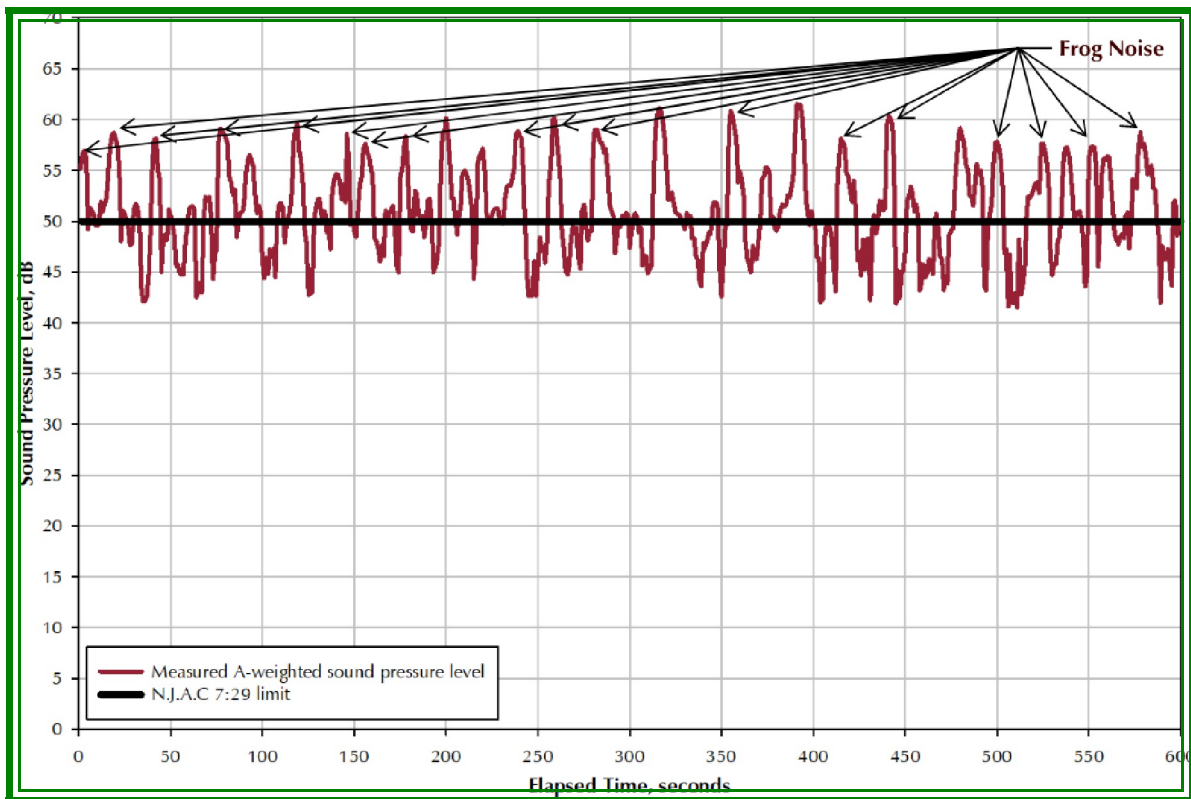


Figure 18. A-weighted sound level time history for measurement at 25 Barton Drive between 2219 and 2229 hours, compared with N.J.A.C. 7:29 limit for residential receivers during nighttime (2200-to-0700) hours. Source: Ostergaard Acoustical Associates).

Clearly, the sound recording data provided by Ostergaard Acoustical Associates shows high levels of vocalization by calling Bullfrogs that should be considered a nuisance to the residence. The results of the acoustical findings from the Bullfrog noise measurements were found to be (at times), well above the Hightstown and the New Jersey Noise Regulation (found at N.J.A.C 7:29), as well as Hightstown Ordinances (2020-13 and 2020-14) noise ordinance (**Figures 17 and 18**).

ARE AMERICAN BULLFROGS INVASIVE ?

The answer is yes! Even though the Bullfrog is native to New Jersey, they have invaded retention ponds 6 and 7, where they were not meant to be. Because of their prolonged 3 to 4 month breeding season, their loud vocal calls and high population density, they have become a nuisance to local residents (Bremner and Park, 2007). The American Bullfrog was introduced to the Pacific Northwest in the late 1920s or early 1930s as a food source. In the last 90 years, the Bullfrog has greatly expanded its range (Clarkson and deVos, 1986). They are larger than native frogs and, in some areas, may have displaced them. In Arizona, California, Washington, this frog is commonly found in many lakes, reservoirs and sloughs. Bullfrogs are highly aquatic and stay close to the borders of lakes (Reinhardt et al., 2003; Adams et al., 2003; Adams and Pearl, 2007).

Their spread throughout the western United States may be due more to illegal releases and floral nursery sales for insect control, than their ability to spread on their own (Mooney and Hobbs, 2000). Where they have been introduced to new ecosystems, Bullfrogs have become an invasive species (Biek, et al., 2002). Without natural predators and that they eat whatever they can, Bullfrogs are causing populations of native species to decline in parts of the western US, Canada, Mexico, South America, Asia and Europe (Pearl et al., 2004; Govindarajulu et al., 2005; Govindarajulu et al., 2006; Louette and Bauwens, 2013; D'Amore, et al., 2009; D'Amore, 2012). Aside from disrupting natural food webs, Bullfrogs also carry diseases that negatively affect other amphibians, including *chytrid* fungus and *Ranavirus* (Reinhardt et al., 2003; Garner et al., 2006; Scalera, 2010; Johnson et al., 2011). It should be pointed out however, that the bullfrog population at *Enchantment at Hightstown* is in good health and showed no sign of infection by the *chytrid* fungus.

WHAT DOES "INVASIVE" MEAN ?

In ecology, an invasive species is one that has been introduced to a new environment and causes harm to indigenous, or naturally occurring organisms. These non-native species repopulate and spread rapidly, disrupting the food chain, competing for habitat, and generally making it harder for indigenous organisms to survive (Doubledee et al., 2003). Invasives can be animals or plants or any kind of living things. In some cases, American Bullfrogs were accidentally introduced to new habitats along with fishing stock. In others, they were purposefully introduced as a food source or by irresponsible pet owners. Needless to say, the Bullfrog is among 100 of the world's worst invasive alien species (Lowe, et al. 2000; Mooney and Hobbs, 2000).

OPTIONS, REMEDIES AND RECOMMENDATIONS

Option One - Removal of Adult Bullfrogs

Objectives are to remove as many adult breeding size Bullfrogs as possible from retention ponds 6 and 7 at *Enchantment at Hightstown*. Since Bullfrogs are considered a game animal, it is legal to harvest them for human consumption in New Jersey with the appropriate Division of Fish and Wildlife, commercial harvest permit. Harvest permits include both Bullfrog and Green Frog (*Lithobates clamitans*). Bullfrogs and Green Frogs may be taken by means of spears, hooks, dip nets (not more than 24 inches in diameter), traps or by hand (Brown, 1997). A person shall not take, kill or have in possession a Bullfrog or Green Frog from April 1 to June 30, which is the yearly seasonal limit. Catchability of Bullfrogs is easier after dark with the aid of a powerful flashlight. Shining the light in their eyes disorients the frog and they can be caught in a dip net. Taking, or attempting to take any other species of frog in New Jersey is prohibited. The Division has a daily limit on the number of Bull Frogs that can be taken that runs from July 1 through December 31, and January 1 through March 31 of each year, which is 15 per day. All Commercial Harvest Permits are valid for use in fresh waters only. Bullfrogs may not be sold unless taken under a Commercial Harvest Permit. Bullfrogs may be taken in numbers greater than the daily limit (15), under a Commercial Harvest Permit that may be issued by the Division at its discretion. To apply for a permit contact the Bureau of Freshwater Fisheries (contact numbers: 908-236-2118 = northern NJ) or at 609-259-6964 = southern NJ). Checks are made payable to NJ Division of Fish and Wildlife.

Can One Eat Bullfrogs ?

The answer is yes. Frog legs have long been considered a delicacy in some cultures. In the southeastern United States, many restaurants serve breaded and fried frog legs on their menus. Bullfrogs have big, meaty legs, which are said to be low in calories and fat and highly nutritious. All of the Bullfrog is edible, but the legs are particularly delicious when properly prepared. Outside of its range, invasive Bullfrogs are causing ecological problems because they have no natural predators. Therefore eating more of these amphibians is one way to help restore balance to the local food chain.

Option 2 - Removal of Tadpoles

Since one pregnant female Bullfrogs can lay between 10,000 to 20,000 viable eggs annually, and there are combined approximately 110 adult females in retention ponds 6 and 7, the population could multiply and duplicate itself indefinitely (Altig and McDiarmid, 2015). One way to reduce the Bullfrogs population at *Enchantment at Hightstown* would be to collect and remove large numbers of tadpoles from the ponds (Provenzano and Boone, 2009; Hauser and McCarthy, 2009; Louette et al., 2013). This could only be done with the approval and a permit from the Division of Fish and Wildlife, NJDEP. Tiger salamander eggs (*Ambystoma tigrinum*), have been translocated from unprotected habitat to protected habitat in Division's Wildlife Management Areas (Zappalorti and Rocco, 1994). The Division allows the removal and relocation of nuisance snakes (harmless and venomous) from people's backyards. The snakes are captured and placed in a ventilated container. Then they are moved a safe distance away and placed back into their natural habitat, thus out of harm's way. This is only done by trained and licenced volunteers or Division staff. Under special conditions, and with the approval of the Director of Fish and Wildlife, NJDEP, the Division could issue a commercial harvest permit to remove tadpoles from retention ponds 6 and 7, but where would they go? A decision would have to be made about what to do with them prior to any collection and removal of the tadpoles. Some possible ideas to consider are:

- 1). Using haul seines and dip nets, Bullfrog tadpoles could be collected and placed in temporary holding containers for transportation. Distribute and place the Bullfrog tadpoles in large ponds, lakes and reservoirs in Division's Wildlife Management Areas where there is an abundance of freshwater game fish, especially large mouth bass (*Micropterus salmoides*), that will eat a percentage of them.
- 2). Using haul seines and dip nets, Bullfrog tadpoles could be collected and placed in temporary holding containers for transportation. With the permission of landowners, distribute and release the Bullfrog tadpoles in old mining ponds. Once the legal limit of sand and gravel is extracted from mining ponds they are often left alone and they naturally succeed into suitable freshwater habitat. The Bullfrog tadpoles would find these old mining ponds suitable and would adapt to more natural surroundings (Zappalorti, 1995; Zappalorti, Metcalf and Torocco, 1995).
- 3). If the Division does not want to trans-locate the tadpoles to other wetland locations in New Jersey, then the final option would be to kill them. Since they are cold-blooded amphibians, the tadpoles could be humanely killed by freezing.



Figure 19. A Largemouth Bass who just ate a Bullfrog, head first. By stocking retention ponds 6 and 7 with Largemouth Bass, it would help to reduce the frog population.

Option 3 - Stock Ponds 6 and 7 with Largemouth Bass

According to the New Jersey Division of Fish and Wildlife, Bureau of Freshwater Fisheries, the largemouth bass (*Micropterus salmoides*) is a member of the sunfish family (*Centrarchidae*) and is native to eastern United States. It is undoubtedly the most popular freshwater game fish and a common pond species (Maceina et al., 1995). Largemouth bass spawn in the spring when the water temperature reaches 60-70 degrees F. Largemouth bass are opportunistic predators and actively consume bluegill, minnows, shad, Bullfrogs and numerous other prey items, including frog tadpoles (**Figure 19**). In smaller ponds, largemouth bass perform best when presented with a variety of forage species. To maximize the growth of largemouth bass in ponds, an abundance of forage of the appropriate sizes must be available to the bass at all times (e.g., Bullfrog tadpoles). Northern largemouth bass can reach 10+ pounds and they are easy to catch by fishermen (Louette, 2012). Stocking retention ponds 6 and 7 with largemouth bass would reduce the Bullfrog population (Mesing et al., 2008).

On June 18, 2021 I requested further information regarding retention ponds 6 and 7 which I understand has been forwarded to the homeowner's association. This information is critical to securing approval from the New Jersey Division of Fish and Wildlife. The additional information may also impact my conclusion above and, accordingly, I request such information as soon as possible.

Since retention ponds 6 and 7 are less than one acre in size and are about four feet in depth at the deepest point, aeration pumps would have to run for a minimum of 16 hours a day. It would be better for the fish if the aeration pumps were on all the time to increase the amount of dissolved oxygen in the water. The ponds would also require some additional aquatic vegetation such as the European white water lily (*Nymphaea alba*), and the yellow water-lily or spatterdock (*Nuphar lutea*). The large floating green leaves would provide shade and help keep the water temperature cooler during the summer months. The pretty white and yellow flowers would be esthetic to look at by the residence and attract various insects such as dragon flies and butterflies. The aquatic plants would provide shade and cover for first-year largemouth bass (Slaughter et al., 2008).

In order to receive a permit from the Division's Bureau of Freshwater Fisheries, as a condition of stocking game fish on private property, the *Enchantment at Hightstown* Homeowner's Association would have to allow the public to fish at retention ponds 6 and 7. The Division of Fish and Wildlife issues a variety of permits related to the long-term protection and wise use of the state's freshwater aquatic resources.

Incomplete applications, or those lacking the required additional information will be returned. Questions concerning this information can be directed to the Bureau of Freshwater Fisheries staff at 908-236-2118 (northern NJ) or at 609-259-6964 (southern NJ). Checks are to be made payable to New Jersey Division of Fish and Wildlife. Allowing the public to fish at the retention ponds should not be a concern. There is no need to advertise such availability to fish and the shoreline within each pond could be limited to designated areas (e.g., the shoreline opposite and furthest away from the homes). The Homeowners Association likely could require an advance registration for people who wish to fish at retention ponds 6 or 7.



Figure 20. An adult female Bullfrog resting on aquatic vegetation.

SUMMARY AND CONCLUSION

The combined total number of Bullfrogs living and breeding in both retention pond 6 and retention pond 7 are: Adult male Bullfrogs = 112, Adult Female Bullfrogs = 110, Sub-adult Bullfrogs = 17, Metamorph Bullfrogs = 14, and Bullfrog Tadpoles = 1,807. Therefore the population estimate is approximately 2,060.

These findings indicate that the noise from 40 or 50 adult male Bullfrogs calling for several hours each day or night is so loud that the sound penetrates the exterior and interior of close-by homes. The Bullfrogs' ongoing sounds result in disturbing and disquieting levels of annoying noise which dominates the personal space of the residents. Furthermore, due to density of the Bullfrogs in retention ponds 6 and 7, the male breeding calls become even louder and more intensive throughout the night. The high frog volume coincides with the time when residents retire for the night. Therefore, it is reasonable to determine that the level of noise from the vocal calls of the frogs can be heard through their bedroom windows when they are trying to sleep. Bullfrog sounds not only penetrate into a resident's bedroom, but at times it is so loud and distressing that it prevents and adversely impacts the resident's sleep. The breeding calls of the Bullfrogs start with intensity at dusk and continue throughout the night at various levels. The acoustical findings from the Bullfrog noise measurements were found to be well above the New Jersey Noise Regulation (found at N.J.A.C 7:29), as well as Hightstown Ordinances (2020-13 and 2020-14) noise ordinance (**Figures 16, 17 and 18**).

Because this particular Bullfrog population is doing so well, is reproducing at an astonishing rate and has a population estimate of 2,060 individuals, they produce high levels of breeding call noise. The vocal breeding calls and the abundance of Bullfrogs at a housing development is not normal (see **Figures 10, 11 and 12**). The residents deserve, and should receive some relief and cooperation from the Homeowners Association and the New Jersey Division of Fish and Wildlife, NJDEP who regulates nuisance wildlife. This population should be reduced by one or more of the methods suggested in this report.

Respectfully submitted,

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