# *American Bullfrogs (Rana catesbeianus) in Eagles Lake: Restoration through Eradication*

*By: Evan Quinn, Joel Wilson, Will Brown, Cayla Naumann*

*ES 341: Ecological Restoration*

Photo credit: http://www.flickr.com/photos/nickharris1/4607755942/sizes/l/in/photostream/

Table of Contents

# Introduction (Will Brown)

## Identification and Ecology

The American bullfrog, *Rana catesbeianus*, is the largest North American frog (body length: 20cm; hind legs to 25cm), and can weigh up to 0.5kg or more (Encyclopedia Britannica, 2010). Its true frog appearance (smooth skin, long hind legs, fully webbed hind feet, and teeth in upper jaw) distinguishes the bullfrog from North American spade foots, toads, tree frogs and narrow-mouthed toads, while its large size and breeding call help to distinguish from North American true frogs (Figure 1; Conant & Collins, 1991).

**Figure 1. American Bullfrogs (*Rana catesbeiana*) (Govindarajulu & Dodd, 2010).**

Adult bullfrogs are semi-aquatic and inhabit a variety of water bodies including swamps, lakes, marshes and stream margins, and can sometimes be found in temporary waters hundreds of metres from permanent water. They are tolerant of cold climates and will hibernate in substrate when temperatures fall below freezing (Santos-Barrera, et al., 2009).

In British Columbia, breeding occurs during June and July, when females can lay between 10,000 to 20,000 eggs at a time. Tadpoles hatch in 3-5 days and begin metamorphose after 1-2 years, reach adulthood after 2 years and begin breeding after 3 years (Govindarajulu P. , 2004; Govindarajulu, Altwegg, & Anholt, 2005).

## Distribution and Invasion

The native range of the bullfrog covers most of eastern North America, from northern Florida to southern Canada; however, this native distribution is dwarfed by their present range (Gherardi, 2007). The adaptability and success of bullfrogs has placed them among the most successful vertebrate invaders, and they are considered by the IUCN Invasive Species Specialist Group to be among the 100 worst invaders in the world (Gherardi, 2007). Bullfrogs now occupy parts of western Canada and many other countries around the world including Brazil, Hawaii, Japan, China, the Netherlands and the UK (Gherardi, 2007).

Escaped and intentionally released bullfrogs farmed for the gourmet market are the primary cause for the spread of bullfrogs worldwide; however, accidental release from trout stockings and the pet trade have also contributed (Gherardi, 2007). In British Columbia, farms were not economically successful and bullfrogs were introduced in the wild in the 1930s (Govindarajulu P. , 2004). The studied bullfrog population at Eagles Lake in the District of Highlands began to establish over a decade ago, as a result of range expansion from populations established in the vicinity of Elk and Beaver Lakes in nearby Saanich (Orchard, Removal of invasive American bullfrogs, 2010).

## Impacts

Bullfrog invasion can have a significant impact on the environment and can affect several aspects of the ecosystem.

Predation: Bullfrogs have a voracious appetite and are highly predatory. Their diet consists of anything that will fit into their mouths including insects and other small invertebrates, birds, small mammals, snakes and other frogs (including other bullfrogs) (Gherardi, 2007; Orchard, Removal of

invasive American bullfrogs, 2010). Tadpole predation on the eggs and larvae of some fish species such as the endangered Razorback Sucker *(Xyrauchen texanus*) also has an adverse impact (Muller *et al.,* 2006). In British Columbia, bullfrog predation significantly affects the native Pacific treefrog (*Hyla regilla*) and the Red-legged frog (*Rana aurora*), which has a COSEWIC status of "vulnerable" and BC status of "blue listed"(Kiesecker & Blaustein, 1998; (Ministry of Environment, 2010). Another "blue listed" species in BC is the Western painted turtle (*Chrysemys picta bellii* ) (Ministry of Environment, 2010). Several hatchlings have been found in the stomach contents of individual bullfrogs, potentially having a very significant impact on western painted turtle hatchling survival in water bodies with bullfrogs present (Orchard, Removal of invasive American bullfrogs, 2010).

Competition: Bullfrogs compete for habitat and food with several endemic species, in particular the native Pacific treefrog (*H. regilla*) and the red-legged frog (*R. aurora*) (Kiesecker & Blaustein, 1998). Larval competition decreases the survivorship and growth of Pacific treefrog (*H. regilla*) and yellow-legged frog (*R. Boylii*) tadpoles (Kupferberg, 1997). All of these competitive factors can contribute to lower survivorship of native species, and increased populations of the invasive American bullfrog.

Disease transmission: Chytridiomycosis, an emerging fungal disease responsible for global ambhipian declines, is spread by invasive bullfrog populations (Hanselmann *et al.*, 2004). Bullfrogs harbour the disease-causing *Batrachochytrium dendrobatidis* but are relatively unaffected (Hanselmann *et al.*, 2004). In North America, several native frog species are affected by this spread of chytridiomycosis, including the Pacific chorus frog (*Pseudacris regilla*), the red-legged frog (*R. aurora*); the plains leopard frog (*Lithobates blairi*); the northern leopard frog (*L. pipiens*); the lowland leopard frog (*L. yavapaiensis*) and many central Californian amphibians. Declines in amphibian populations have occurred in parts of Europe and Venezuela, where the American bullfrog is also an invasive species (Hanselmann *et al.*, 2004).

Ecosystem change: Bullfrog tadpoles can alter biomass, structure and composition of algal communities (Flecker, Feifarek, & Taylor, 1999). Due to high food intake and high population densities, tadpoles can also have a significant effect on nutrient cycling and primary production (Pryor, 2003).

These combined factors of predation, competition, disease transmission and ecosystem change have negative impacts on native species and the habitat as a whole. Without the American bullfrog present, the ecosystem can gradually recover and return to its pre-disturbance state without significant human interference; however, the continued presence of the American bullfrog and potential population increase could have extremely detrimental effects on native species and habitats, potentially leading to the loss of some endangered species, like the Western Painted Turtle, altogether.

## Methods of Control

Despite the significant evidence of the ecological impact of bullfrog invasion, there is a lack of resources necessary to attempt large-scale management because of the lack of obvious economic impact compared to other invasive species (Gherardi, 2007). There are, however, several methods to prevent the invasion of this species:

Prevention: This is considered the best way to prevent the introduction or establishment of invasive species in new areas. It is considerably easier to attempt eradication if the species has a limited distribution (Gherardi, 2007). While it appears impossible to prevent bullfrog escape from aquaculture operations, Hanselmann *et al.* (2004) suggest trade and introduction of amphibians should be monitored and traded amphibians should be subject to veterinary surveillance and quarantine to prevent the spread of chytridiomycosis.

Direct removal: This involves either removing or killing individuals, of which there are several different methods. Banks *et al.* (2009) used lamps to collect frogs at dusk, using fencing around the main ponds to limit dispersal. The ponds were drained and sediment removed to remove remaining

frogs and larvae. While this did not result in complete eradication, limited breeding was detected the next summer. There are a range of other techniques that may be used for direct removal such as funnel traps, gigs, guns, electric shock, and hand removal (Gherardi, 2007). Collecting egg masses in combination with killing frogs and tadpoles can be effective. Direct removal techniques are hampered by strong density dependence during both the larval and post-metamorphic life stages. It is suggested reducing the survival of juveniles rather than other life stages would be the most successful (Vonesh & de la Cruz, 2002).

Habitat manipulation: It is possible to manage habitat and landscape characteristics to limit the dispersal of bullfrogs. Maret *et al.* (2006) found that drying could be used to eliminate bullfrogs in livestock watering ponds as larvae depend on permanent water for growth. A combination of periodic pond draining in combination with adult removal can be an effective strategy. Habitat segregation can reduce both predation and competition, while increasing structures such as vegetation can reduce the effectiveness of some predators by reducing encounter rates (Gherardi, 2007). While there is extensive theoretical evidence that the alteration habitat characteristics can limit the impact of bullfrog invasion, more research needs to be carried out, with particular focus on the effects on indigenous species.

Community characteristics: The differences in ecology between larval bullfrogs and other temperate ranids can be used to reduce the impact of bullfrog invasion (Gherardi, 2007). 'Facilitator' species such as sunfish can increase the survival of bullfrog larvae by feeding on bullfrog predators (Gherardi, 2007). Limiting the spread or intentional introduction of these 'facilitator' species may help limit the spread or abundance of bullfrogs (Gherardi, 2007). It has also been suggested indigenous macro-invertebrates can restrict bullfrog populations to low enough densities to allow native species to persist (Gherardi, 2007). Such research could be used to control features of wetlands to increase macro-invertebrate density and control bullfrog abundance (Gherardi, 2007).

Although prevention, direct removal, habitat manipulation and community characteristics are all potential ways of limiting or controlling American bullfrog populations, the best method can only be determined by individual site characteristics. The impact of the activity and the potential effectiveness of the activity at a given site must be taken into account in order to determine the best protocol for removal of the bullfrogs and restoration of a site to its structure prior to bullfrog introduction. The site description is critical to determining the best outline for removing the invasive species from the area.

## Site Analysis Eagles Lake (Joel Wilson)

Site description gives insight into the controlling environmental factors and the habitat values that help us understand the ecosystem function. Eagles Lake is a small spring-fed lake in the District of the Highlands, which is a rural residential area just northwest of Victoria, B.C., Canada (Figure 2; Figure 3). More than one third of the Highlands is protected municipal, regional and provincial parkland (The District of Highlands, 2010). Eagles Lake is a tiny municipal park used as a community "swimming hole". While there is historical evidence of First Nations use in nearby parks, there is no information specific to this site; however, the Highlands is part of the Te'mexw Treaty advisory council (The District of Highlands, 2010). Eagles Lake was chosen for our restoration project because it is an example of an area currently threatened by bullfrogs and it is part of a valuable and complex ecosystem. It is small area that could easily be overlooked by organizations trying to restore larger habitat areas, but is well-recognized in the community as a place of ecological significance and provides a connection to nature that may not otherwise be present.

In undertaking our project we are seeking to adhere to the three main objectives as proposed by the Parks Canada's *Principles and Guidelines for Ecological Restoration* (2008) which are: to be *effective* in achieving our goal, to be *efficient* by using well thought out methods and to be *engaging* where we recognize the important connection between nature and culture. Eagles Lake is

a valuable community asset for the Highlands district, and any restoration projects would need to involve the local community and examine the needs of the community with that of the ecosystem (Society for Ecological Restoration B.C. Chapter, 2010). Restoration efforts should focus on the removal of invasive species as an important means of maintaining the recreational and ecological value.

**Figure 2 View of Eagles Lake (The District of Highlands, 2010).**


**Figure 3 Google map view of Eagles Lake.**

## Abiotic Conditions

The Highlands are in the biogeoclimatic zone classified as the coastal Douglas- Fir Zone (Figure 4). This is the smallest of the fourteen biogeoclimatic ecological zones within B.C. It is a low elevation coastal area of Vancouver Island (<150m) (Ministry of Forests and Range, 2008). The climate is characterized by warm, dry summers and mild, dry winters with limited snow. The vegetation is primarily Douglas- fir, Hemlock and Western Cedar forest. The Highlands lies within the Georgia Depression Ecoprovince, which encompasses the southeastern corner of Vancouver Island. This is an area where wetlands are common and there are ecosystems that cannot be found anywhere else in B.C. (Ministry of Environment, 2010).

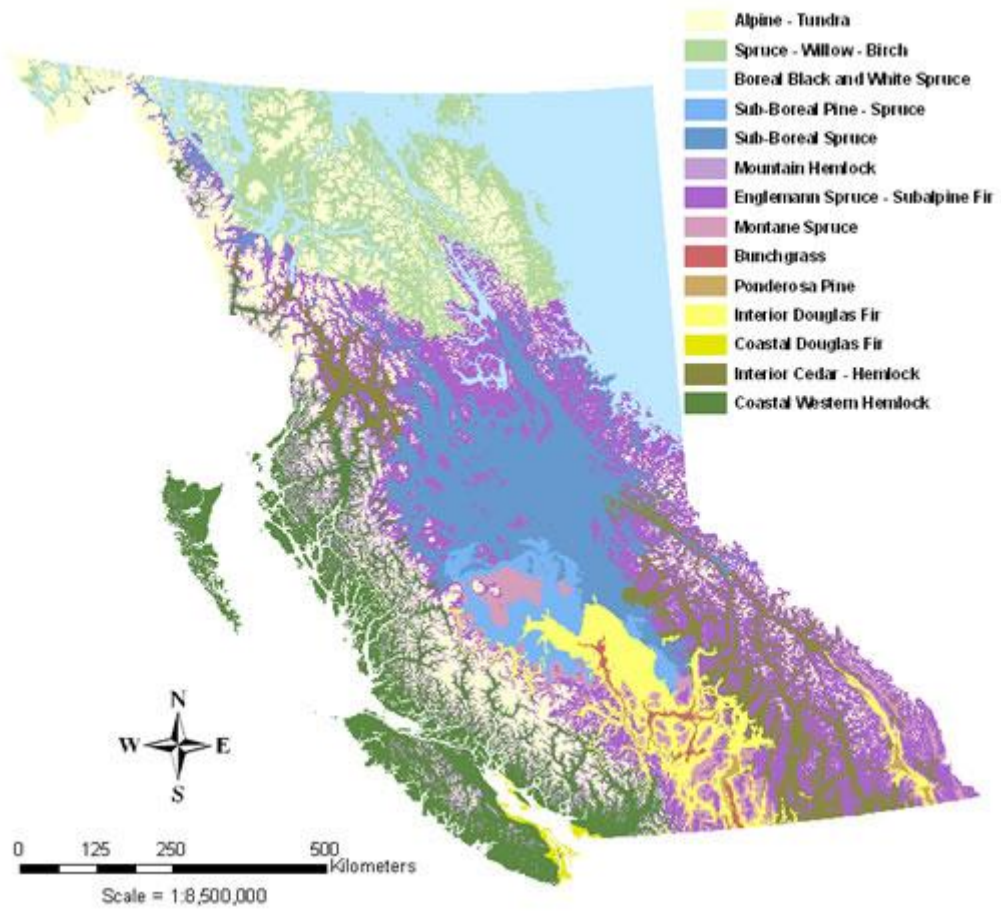


**Figure 4 Biogeoclimatic zones of British Columbia (Ministry of Forests and Range, 2008).**

Highlands Sustainability Task Force noted in their environmental assessment that there is limited detailed information on the region, information is urgently called for. The Federal/Provincial Sensitive Ecosystems Inventory has mapped several sensitive ecosystems on East Vancouver Island with a large number of those being in the Highlands. Eagles Lake Park includes several of the ecosystem types noted including:

- Older Forests (coniferous average tree age > 100 years)
- Woodlands (deciduous and mixed)
- Wetlands ( ponds, marshes, lakes)
- Riparian (streamside vegetation)

(Ministry of Environment, 2010)

Eagles Lake Park is in the Craigflower Creek Watershed, which drains the central and eastern portions of the Highlands (The District of Highlands, 2010). Precipitation is the primary source of groundwater recharge. The annual precipitation is approximately 1205 mm with most recorded between October and March. The average monthly temperature is 9.7 degrees Celsius ranging from 3.8 in January to 16.1 in July (Golder Associates, 2009). All of these features contribute to the unique habitat and features created at Eagles Lake, and are important in determining the best method for eradication of the American bullfrog.

Urbanization has fragmented the landscape near the lake. A road that is now paved runs alongside the lake. Parking is an issue and parked cars have disturbed the borders of the road further. What is important to note is that the Highlands residents are committed to trying to preserve the rural nature of their community. A Highlands Lake Stewardship Association exists to combat negative human impact. One example is the installation of a composing cob toilet for visitor use. This has a resource capture system, and due to thermophilic composting, the toilet does not attract vermin, generates high temperatures and self pasteurizes (The District of Highlands, 2010). This is evidence that there is community support for maintaining the natural state of the lake. The Highlands has a strong record of community involvement and volunteering, such as annual Scotch broom removal parties (The District of Highlands, 2010). If concerned residents could be educated to a restoration problem such as the American bullfrog, the workload towards eradicating the invasive species could be shared, making the program more effective and sustainable in the long term.

## Biotic Conditions

Eagles Lake Park is part of a riparian ecosystem. Eagles Lake is a wetland area where water saturated soil results in low soil oxygen levels, which is a main determinant of the existing

vegetation. Hydrodynamics are important for soil moisture, and contribute significantly to the plant and animal community structure (Ministry of Forests and Range, 2008). There is an abundance of hydrophytes, which are plants that can grow in waterlogged soil. The plant species commonly found at the site include native and non-native water lilies, bladderwort, native and non-native Elodea, Potamogeton, sinkfoil, Eurasian millfoil, mats of filamentous algae, duckweed, cattails, reeds, native willows, red dogwood (Orchard, Removal of invasive American bullfrogs, 2010). There are cedar trees with an undergrowth of salal (*Gaultheria shallon*), gorse (*Ulex* sp.) and Himalayan blackberry (*Rubus discolour*) close to the water edge. Short distances further from the lake edge were Arbutus trees (*Arbutus Menziesii*) with Oregon Grape (*Mahonia aquifolium*) and sword ferns (*Polystichum munitum*) beneath. These were overshadowed by a Douglas- fir (>10m) canopy.

While small enough that local residents call it a pond or a "swimming hole", Eagles Lake is distinguished as a lake, as it is deep enough that light cannot penetrate to the bottom. Bacteria is present in the form of decomposing organic material (although the lake is spring fed the water movement is not dynamic )(Ministry of Forests and Range, 2008). The wide range of vegetation supports many types of wildlife including owls, such as the Great-horned owl (*Bulbo virginianus*), Stellar's Jay (*Cyanocitta stelleri*), various woodpeckers, black tailed deer (*Odocoileus hemionus*), raccoons (*Procyon lotor*), and mink. It also contributes significant habitat area for larger mammals such as black bears (*Ursus americanus*) and cougars (*Puma concolor*).

## Invasive Species

The ecology of the Eagles Lake natural area is severely threatened by non-native plants and animals such as Scotch broom, gorse, bullfrogs, grey squirrels and black slugs (Ministry of Environment, 2010). Our project focus is on the impact of the invasive American bullfrog. The American bullfrog is an exotic species that has been moved from its natural range and introduced to Vancouver Island. This movement is commonly associated with human activity and the close proximity of the lakeside to the road and the new resident acreages could have introduced the

invasive species to Eagles Lake; however, the species likely introduced itself to Eagles Lake after spreading from Elk Lake or another nearby lake infested with American bullfrogs (Orchard, Removal of invasive American bullfrogs, 2010). Advertising of the park as a "rural gem" on the Highlands website, which has a link to the CRD parks website, has brought many visitors. The ecosystem is feeling the impact of increased pedestrian traffic, but with increased education and signage at the site Eagles Lake could serve as an excellent example of removal of an invasive species and serve to prevent further spread and introduction of the American bullfrog at other sites.

# Policy, Goals, and Objectives (Evan Quinn)

## Policy: Why remove American Bullfrogs in Eagle Lake?

As an invasive species of the ecosystem of the Victoria Highlands, the American bullfrog is having detrimental effects on the levels of biodiversity in the area. The removal of this species is key in establishing healthy numbers and populations of native species. Although there are currently efforts being undertaken to reduce the bullfrogs numbers it has not been enough, and populations persist in many bodies of water. Removal of bullfrogs will help to bring back ecosystem services within the region. By restoring this environment, we are simultaneously restoring the ecosystem back to its reference conditions resulting in a naturally functioning healthy site.

## Goals

Primary Goals: To eradicate the populations of American Bull Frog (*Rana catesbeiana*) present in Eagles Lake, the dominant invasive species as a primary means of restoring appropriate populations of native species and the functionality of the site.

The removal of the invasive species will follow the set principles assigned by the Parks Canada Ecological Restoration Principles and guidelines (2008). The proposed removal must be effective in restoring and maintaining the ecological integrity of Eagles Lake; efficient in its use of

funding to achieve successful removal within a designated budget and time scale; and engaging by means of community integration and education as recognition of the interconnectedness of culture and ecology. Successful restoration of Eagles Lake is dependent on:

Section 1.) Site analysis of biotic, abiotic, and cultural features of Eagles Lake.

Section 2.) Identification of Eagles Lake values and objectives to successfully accomplish the project goals.

Section 3.) A design that involves community collaboration and input.

Section 4.) Careful implementation of project design

Section 5.) A continuous monitoring plan to ensure continued eradication of American bullfrogs in Eagles Lake

To ensure long-term success, this project must not only focus on the removal of the American bullfrog but also on continuous monitoring of Eagles Lake for reintroduction. Public consultations will focus on increasing community awareness of the current and ongoing removal efforts and education on the rationale behind the efforts. Collaboration and dialogue between public, restorationists, and all municipalities affected by the invasion of the American bullfrog will be of great importance for the long-term successful removal of the invasive species.

## Values and Important Features

### Biophysical Values

Invasion of the American bullfrog has negatively affected species, directly and indirectly. This includes the red listed species: the western painted turtle, red-legged frog, and coho salmon. These species contribute not only biodiversity and ecological function to the region, but are economically important.

### Social Values

Residents of the Highlands have been affected by the presence of the loud invasive species. Residential ponds have become a spawning pool for the American bullfrog. Noise pollution from calling bullfrogs has become an issue, with some residents even considering moving from the area (Orchard, Bullfrog Eradication Program Results-Highlands District Ponds 2010, 2010). The waters of residential ponds are warmer and are attract bullfrogs as bullfrogs migrate from colder ponds to warmer ponds (Orchard, Removal of invasive American bullfrogs, 2010). Residents need to be informed of the Bullfrog biology and the ecological ramifications of this invasive species

### Directions for future efforts

Efficient restoration is a dedication to insure long-term success and monitoring in the years to come. Incorporation of new sciences, practices, knowledge, and creativity in dealing with newfound problems is part of the future sustainability of a projects life span. An overarching long-term goal that encompasses social, biological, and economic values will insure the integrity of Eagles Lake free of invasive species for future generations. Adaptability and acceptance of new information needs to be incorporated to ensure that the removal and restoration plan is effective into the future.

## Objectives

### Biological objectives

- To eradicate the American Bullfrog population within Eagle Lake to zero percent within three years of program start date.
- To prevent the continued loss of biodiversity in native species within Eagles Lake and the surrounding ecosystems
- To remove bullfrog populations without the use of chemicals or extermination methods that have the potential to harm other species within the area
- To ensure and plan for ongoing active management of the bullfrogs in Eagles Lake through the creation of a comprehensive ongoing management and monitoring plan.

- To insure the resilience of the ecosystem to further invasive species harm by constant monitoring
- To protect aesthetic and noise values of nearby residence
- To ensure that restoration activities do not harm or interfere with existing native biodiversity

### Social objectives

- To engage the public prior, as well as during, the removal of the bullfrogs
- To insure the public acknowledges the ecological values that the bullfrog removal will have and its feasibility
- To hold a public hearing before each removal process (in early April before metamorphosis occurs)
- To hold a public hearing after the three years of implementation for all parties and groups interested in the quantitative data collected from the removal of the bullfrogs
- To create public awareness about the implications of bullfrog invasions by use of educational signs in the surrounding communities of the Highlands and through the creation of an informative and instructional brochure/newsletter to be distributed by the municipality of the Highlands and to willing community outlets.
- To increase efficiency and effectiveness of the restoration project by providing public information of the species physical features and how to remove them safely and efficiently without disturbing the lake site further
- To insure future Environmental Studies 341 students have access to the proposed project and its value as a invasive species restoration example

# Implementation (Cayla Naumann)

## Site Preparation

In order to restore Eagle Lake, the bullfrogs must be completely eradicated. The bullfrogs have substantially affected the abundance and biodiversity of wildlife at Eagle Lake, and could create a public health concern (Orchard, Removal of invasive American bullfrogs, 2010). The site would be somewhat challenging to work on due to the large amount of vegetation and debris in the lake (Orchard, Removal of invasive American bullfrogs, 2010). This makes it difficult to find the bullfrogs, and manoeuvre to capture them (Orchard, Removal of invasive American bullfrogs, 2010). While there are no preparations of the site required before removal of the bullfrogs, some calculations can be made to estimate the required effort and costs to remove the bullfrogs.

## Protection of the Site

Stan Orchard's method of removing the bullfrogs is low impact, with minimal effect on the habitat or other organisms in the habitat. Because of the targeted removal of the bullfrogs, one of the most important aspects of removing them is excellent frog identification skills. This is one of the barriers to use of volunteers or expansion of the program. Stan Orchard wants to ensure that no native species are mistakenly stunned or removed from the habitat due to misidentification (Orchard, Removal of invasive American bullfrogs, 2010). The amount of lakeside vegetation and debris also influences the ease of which bullfrogs can be removed from a given site. Sites with significant vegetation and debris are more likely to be damaged, but removal of bullfrogs early in the year before significant vegetative growth can minimize the impact of removal and increase success of bullfrog removal (Orchard, Removal of invasive American bullfrogs, 2010).

## Removal of Bullfrogs

According to Francesca Gherardi (2007) "bullfrog populations are often either difficult or impossible to eradicate depending on habitat and landscape features". The difficulty in removing

them is compounded by the fact that they are representative of a suite of non-indigenous species characterized by 1) a broad invasion that is well established in some areas; 2) a relative lack of obvious economic impacts and 3) a lack of reasonable, feasible control methods. Because of these characteristics, bullfrogs, and other similarly classified species, do not attract the resources necessary to remove them (Gherardi, 2007).

Removal of the bullfrogs can be accomplished through direct removal of bullfrogs, habitat manipulation, or community characteristics (Gherardi, 2007). In the literature, there is significant debate over the most effective age group to target for removal to yield the best results; however, Stan Orchard is confident that his method of removing bullfrogs is effective and efficient and has proven results to date. Habitat manipulation is most easily accomplished through the course of other management activities (Gherardi, 2007), and if restorations of Eagles lake, or other bodies of water, was needed then habitat manipulation should be considered to discourage bullfrog populations from establishing.

In Victoria, Stan Orchard, owner of BullfrogControl.com Inc. has effectively removed American bullfrogs from several bodies of water in the District of Highlands near Victoria, BC (Orchard, Bullfrog Eradication Program Results-Highlands District Ponds 2010, 2010; Orchard, Removal of invasive American bullfrogs, 2010). Eagles Lake biophysical makeup is rich with vegetation, a non-motorized boat is essential for both avoiding disturbance and for manoeuvrability. He captures the adults and juveniles using electro-shocking (Orchard, Removal of invasive American bullfrogs, 2010). A two-man crew, in a small paddle-powered zodiac, using high-powered floodlights to spot the adult and juvenile bullfrogs, then stuns and captures the juvenile and adult bullfrogs (Orchard, Removal of invasive American bullfrogs, 2010). The frogs are then chilled, to sedate them, and frozen to kill them (Orchard, Removal of invasive American bullfrogs, 2010). The bodies were used as education tools in classrooms for dissections or have previously been donated to WildArc wildlife rehabilitation centre as a food source for rehabilitated wildlife (Orchard, Removal of invasive

American bullfrogs, 2010). This method has proved very effective, with minimal impact on the environment or other species.

### Budget and Timeline

Based on communication with Stan Orchard, it costs $400 per night for "a two-person team and transportation, liability insurance, equipment, euthanizing the catch, examining and measuring the catch, and analysis and write-up of results" (Orchard, Bullfrog Eradication Program Results-Highlands District Ponds 2010, 2010). For an individual lake, depending on size, it usually takes one or two nights a year for about 3 years to ensure all of the bullfrogs are removed. Continued monitoring post year 3 removal is needed to ensure the bullfrogs do no re-establish from other sites.

We estimate, based on Eagles Lake's size and vegetative cover, that it would take two nights of removal the first year and one night for two additional years. This would be a total cost of $1,600 over three years. The unfortunate reality is there is very limited funding for bullfrog removal projects. The Province is resistant to providing funding, and currently it is up to individual municipalities to provide the funding. The District of the Highlands seems open to continuing eradication of the bullfrog in their region; however, they are pursuing additional funding from the province (Orchard, Bullfrog Eradication Program Results-Highlands District Ponds 2010, 2010).

## Management (Cayla Naumann)

Once bullfrogs have been removed from Eagle Lake, the most important management objective is preventing further invasion and establishment. This includes preventing wild bullfrog populations from re-establishing at the lake and increasing education and awareness to prevent other introductions of bullfrogs from other sources (e.g. escaped or released individuals that were pets, in aquaculture facilities, in research and teaching or failed business endeavours) (Gherardi, 2007).

### Routine Scheduling

Eagles Lake should be monitored weekly in the early spring for signs of bullfrog reestablishment. Spring monitoring is essential to catch signs of the bullfrogs before they have laid eggs that would require removal over the following three years, as the eggs hatched and tadpoles matured to juveniles (Orchard, Removal of invasive American bullfrogs, 2010). The interest of the Highlands Stewardship Foundation in removal of the bullfrogs is a likely source of volunteers willing to monitor the site for bullfrogs. Stan Orchard has already praised the society for their participation in an education workshop, so participation in monitoring would not be much more work, and there is likely interest and enthusiasm for the program (Orchard, Removal of invasive American bullfrogs, 2010).

## Monitoring and Evaluation (Cayla Naumann and Evan Quinn)

After the initial removal of bullfrogs from Eagles Lake, continued monitoring needs to occur to ensure the species does not re-establish. The first year of removal can usually remove all of the adults and juveniles at the time (Orchard, Removal of invasive American bullfrogs, 2010); however, eggs and tadpoles remaining in the pond will usually take a year or two to reach maturity and be captured according to the methods described by Stan Orchard. American bullfrogs are highly mobile species and seek out new bodies of water to inhabit, so surrounding bodies of water that continue to harbour bullfrogs can act a source populations for Eagles Lake. Monitoring of a specific site is key; however, due to the species mobility surrounding ponds and bodies of water must be monitored for possible invasive species presence. Consistent monitoring will need to be met by the community through weekly observations. If presence of re-invasion is noticed immediate attention must be brought to officials within in the municipality so that the individuals and be removed. In order to ensure continued eradication of the bullfrog, bullfrogs need to be removed from the entirety of Southern Vancouver Island. Once the island is cleared of bullfrogs, education and awareness is the most important factor to prevent re-establishment of American bullfrogs on Vancouver Island.

## Conclusion (All)

The American bullfrog is one of the worst invasive species on the planet. It has significant impacts on many species on Vancouver Island, including the red-listed Western Painted Turtle, Red-legged frog, and economically important Coho Salmon. Although Eagles Lake is a relatively small body of water, every habitat eradicated of American bullfrogs is a step towards eradicating them from Vancouver Island as a whole. Based on the expertise of Stan Orchard, removal of the species from Vancouver Island is the best goal for sustainable protection of the unique and biologically diverse habitats on Southern Vancouver Island. Once the species has been completely removed from the island, education and awareness should be sufficient to prevent re-introduction of the invader, and are much less expensive the continued removal of the species from individual sites.

*We do not inherit the earth from our ancestors, we borrow it from our children.*

*~Native American Proverb*

## Works Cited


Banks, B., Foster, J., Langton, T., & Morgan, K. (2000). British Bullfrogs? *British Wildlife , 11*, 327-330.

Canada Parks Council and Parks Canada, National Parks Branch. (2008). *Principles and Guidelines for ecological restoration in Canada's protected natural areas.* Gatineau, Quebec: National Parks Directorate, Parks Canada Agency.

Conant, R., & Collins, J. (1991). *Reptiles and Amphibians Eastern/Central North America.* Boston: Houghton Mifflin Company.

Encyclopedia Britannica. (2010). *Bullfrog*. Retrieved November 28, 2010, from Encyclopedia Britannica Online: http://0-www.britannica.com.library.newcastle.edu.au/EBchecked/topic/84456/bullfrog

Flecker, A., Feifarek, B., & Taylor, B. (1999). Ecosystem Engineering by a Tropical Tadpole: Density-Dependence Effects on Habitat Structure and Larval Growth Rates. *Copeia , 1999* (2), 495-500.

Gherardi, F. (2007). In *Biological invaders in inland waters: Profiles, distribution, and threats* (pp. 679-693). London: Springer.

Golder Associates. (2009). *Phase 2: Ground Water protection Study District of Highlands.*

Govindarajulu, P. (2004). Introduced bullfrogs (Rana catesbeiana) in British Columbia: Impacts on native Pacific treefrog (Hyla regilla) and red-legged frogs (Rana aurora).

Govindarajulu, P., & Dodd, M. (2010). *The Bullfrog Project*. Retrieved November 6, 2010, from http://web.uvic.ca/bullfrogs/

Govindarajulu, P., Altwegg, R., & Anholt, P. (2005). Matrix modle investigation of invasive species control: bullfrogs on Vancouver Island. *Ecological Adaptations , 15* (6), 2161-2170.

Hanselmann, R., Rodriquez, A., Lampo, M., Fajardo-Ramos, L., Alonso Aguirre, A., & Marm Kilpatrick, A. (2004). Presence of an emerging pathogen of amphibians in introduced bullfrogs (Rana catesbeinanus) in Venezuela. *Biological Conservation , 120* (1), 115-119.

Kiesecker, J., & Blaustein, A. (1998). Effects of Introduced Bullfrogs and Smallmouth Bass on Microhabitat Use, Growth, and Survival of Native Red-legged Frogs (Rana aurora). *Coservation Biology , 12* (4), 776-787.

Kupferberg, S. (1997). Invasion of a California River: The Role of Larval Competition. *Ecology , 78* (6), 1736-1751.

Maret, T., Snyder, J., & Collins, J. (2006). Altered drying regime controls distribution of endangered salamanders and introduced predators. *Biological Conservation , 127*, 129-138.

Ministry of Environment. (2010). Retrieved November 6, 2010, from Sensitive Ecosystem Inventories: http://www.env.gov.bc.ca/sei/

Ministry of Environment. (2010). *Environmental Stewardship Division*. Retrieved November 6, 2010, from B.C. Frogwatch Program: http://www.env.gov.bc.ca/wld/frogwatch/whoswho/factshts/bullfrog.htm

Ministry of Environment. (2010). *Reptiles of British Columbia*. Retrieved November 6, 2010, from Western Painted Turtle: http://www.bcreptiles.ca/turtles/westernpaint.htm

Ministry of Forests and Range. (2008). *Biogeoclimatic Ecosystem Classification Program*. Retrieved November 6, 2010, from http://www.for.gov.bc.ca/hre/becweb/

Muller, G., Carpenter, J., Thornbrugh, D., & Bestgen, K. (2006). Bullfrog tadpole (Rana catesbeianus) and red swap crayfish (Procambarus clarkii) on early life stages of endangered razorback sucker (Xyrauchen texanus). *The Southwestern Naturalist , 51* (2), 258-261.

Orchard, S. A. (2010). *Bullfrog Eradication Program Results-Highlands District Ponds 2010.* Victoria: BullfrogControl.com Inc.

Orchard, S. A. (2010, October 13). Removal of invasive American bullfrogs. (C. Naumann, E. Quinn, & J. Wilson, Interviewers)

Pryor, G. (2003). Growth rates and digestive abilities of bullfrog tadpoles (Rana catesbeinana) fed algal diets. *Journal of Herpetology , 37* (3), 560-566.

Santos-Barrera, G., Hammerson, G., Hedges, B., Joglar, R., Inchaustegui, S., Kuangyang, L., et al. (2009). *Lithobates catesbeianus In: IUCN 2010 IUCN Red List of Threatened Species.* Retrieved November 27, 2010, from www.iucnredlist.org

Society for Ecological Restoration B.C. Chapter. (2010). *Ecosystems of B.C.* Retrieved November 6, 2010, from www.ser.org/serbc/bcecosystems.asp

The District of Highlands. (2010). Retrieved November 6, 2010, from The District of the Highlands: http://www.highlands.bc.ca/

Vonesh, B., & de la Cruz, O. (2002). Complex life cycles and density dependence: assessing the contribution of egg mortality to amphibian declines. *Oecologia , 133*, 325-333.