BEST MANAGEMENT PRACTICES FOR

American Bullfrog

in the Metro Vancouver Region

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SERVICES AND SOLUTIONS FOR A LIVABLE REGION

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INVASIVE SPECIES COUNCIL OF METRO VANCOUVER

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Introduction

The impacts of invasive species on ecological, human and economic health are of concern in the Metro Vancouver region. Successful control of invasive species requires concerted and targeted efforts by many players. This document – "**Best Management Practices for American Bullfrog in the Metro Vancouver Region**" – is one of a series of species-specific guides developed for use by practitioners (e.g., local government staff, crews, project managers, contractors, consultants, developers, stewardship groups and others who have a role in invasive species management) in the region. Together, these best practices provide a compendium of guidance that has been tested locally by researchers and operational experts.

American bullfrogs (*Lithobates catesbeianus*)[1] are large, robust frogs native to eastern North America that have become well established on British Columbia's south coast (Province of BC, 2020). They were introduced to British Columbia starting in the 1930s as a delicacy for human consumption (BC Frogwatch, 1993). They have since escaped or have been released into natural areas in western North America (SeaGrant, 2020). Their high reproductive rate, limited predation, and ability to thrive in human disturbed habitats have allowed these invasive amphibians to establish and spread quickly (SeaGrant, 2020).

There is little encouragement regarding the prospects for successful eradication of bullfrogs based on the literature (Centre for Agriculture and Bioscience International, 2020). In fact, experts agree that bullfrog eradication is cost prohibitive and likely impossible in Metro Vancouver. Instead, efforts for this species are focused on preventing new introductions and spread (SeaGrant, 2020), and mitigating the impacts to native frog populations and ecosystems (Switzer, 2020). Management of American bullfrog is often associated with species at risk or wetland habitat enhancement projects, where controlling them is part of a comprehensive, long-term plan.

Academic institutions, government, non-government organizations, and other experts continue to research which methods work best where, and for which life stage, in British Columbia and adjacent jurisdictions. As researchers and practitioners learn more about the biology and control of American bullfrog, it is anticipated that the recommended best management practices will change. This document will be updated to reflect these changes as the information becomes available. Please check metrovancouver.org regularly to obtain the most recent version of these best management practices.

[1] *Lithobates catesbeianus* is also known as *Rana catesbeiana*. They are referred to as American bullfrogs or bullfrogs in this document.

REGULATORY STATUS

Section 2 (1) (b) (iii) of the Community Charter, Spheres of Concurrent Jurisdiction – Environment and Wildlife Regulation, states that "municipalities may regulate, prohibit and impose requirements in relation to control and eradication of alien invasive species", which includes American bullfrog.

American Bullfrog is listed in Schedule C of the *BC Wildlife Act* and Wildlife Act Designation and Exemption Regulation which lists wildlife species that can be captured and killed anywhere and at any time in British Columbia (permission from the landowner is required).

Although not a regulation, bullfrogs are listed under the regional containment/control category on the Provincial Priority Invasive Species list. Species in this category are high risk and well established, or medium risk with high potential for spread; the management objective is to prevent further expansion into new areas within the region through establishment of containment lines and identification of occurrences outside the line to control.

This adult bullfrog eating a juvenile bullfrog demonstrates how easy it is for adults to eat smaller frogs

CREDIT: ALEESHA SWITZER

IMPACTS

Bullfrogs are voracious, unspecialized predators, eating a variety of prey (Jancowski & Orchard, 2013). Much research has been focused on bullfrog interaction with native fauna and their impacts on native ecosystems (Zevit, 2019). They seem immune to the various natural defences of prey species, such as the toxicity of rough-skinned newts and the stingers of bees and wasps, all which have been found in bullfrog stomach content analysis with no apparent impacts (Jancowski & Orchard, 2013). The most concerning aspect of their diet is the consumption of other frogs. Most of British Columbia's native frogs are easily consumed by bullfrogs, and there is evidence that bullfrog colonisations of wetlands are followed by declines in species at risk such as the Northern Red-legged Frog and Oregon Spotted Frog (BC Frogwatch, 1993) (Fraser Valley Conservancy, 2020). Bullfrog adults and tadpoles pursue similar habitat and food sources as native frogs, but bullfrogs can tolerate much more degraded habitat (Zevit, 2019). Bullfrogs have also been blamed for the decline of snakes and other amphibians, whose young fall prey to adult bullfrogs (SeaGrant, 2020).

Bullfrogs may carry the ranavirus and the chytrid fungus (*Batrachochytrium dendrobatidis*) that negatively affects frogs around the world (SeaGrant, 2020). Chytrid fungus causes a thickening of the skin and can eventually cause death to afflicted amphibians who rely on their skin to breath.

Bullfrog tadpoles can alter ecosystems by changing the structure and composition of algal communities (Quinn, Wilson, Brown, & Naumann, 2010). Water supply infrastructure damage may occur if bullfrogs invade these areas (SeaGrant, 2020).

REPRODUCTION AND SPREAD

Female American bullfrogs can lay up to 20,000 eggs at one time (Province of BC, 2020), allowing populations to expand rapidly. Native frogs and toads typically lay fewer eggs.

Adult and juvenile bullfrogs can travel between 3.2-11.5 kilometres per year (Davies, et al., 2020), dispersing to new ponds. Adults are more often seen travelling in the spring while juveniles travel in the fall, after metamorphosis (Province of BC, 2020). Their ability to travel long distances on land and colonize new areas is not seen in native amphibians in Metro Vancouver (Switzer, 2020). The ability of bullfrogs to survive in a wide variety of habitats and feed on a variety of prey, further aid their dispersal into new areas and reintroduction into previously managed areas (Province of BC, 2020).

Bullfrog spread has been aided by humans in the following ways (SeaGrant, 2020):

- Aquarium pets released into the wild when they become too large or unsuitable for home aquariums
- Commercial sales for stocking backyard ponds (Province of BC, 2020)
- Releases at various life stages from school projects
- Introduction for aesthetics of a habitat
- Farmed as a food source and escaped
- Conversion of temporary wetlands to permanent ponds (Govindarajulu, Altwegg, & Anhold, 2005)
- Introduction to western States in early 1900's by settlers as a game species (Clarkson & deVos, Jr., 1986) and subsequent migration into BC
- Accidental release of tadpoles during fish stocking in US States (Clarkson & deVos, Jr., 1986) and subsequent migration into BC

HABITAT AND DISTRIBUTION

American bullfrogs prefer permanent, warm, shallow, ponds and lakes with thick vegetation (BC Frogwatch, 1993). They can also be found in ditches and slow-moving streams (Province of BC, 2020), but prefer standing water. Bullfrogs have adapted to human-disturbed habitats (Province of BC, 2020) and may take up residence in backyard ponds (BCSPCA, 2018). They can tolerate freshwater to brackish habitats (Davies, et al., 2020). More than most native frogs, bullfrogs rely on aquatic environments and adults spend most of their time the water (BC Frogwatch, 1993). To successfully reproduce, ponds or waterbodies must be permanent, as bullfrog tadpoles require water to overwinter their first year (BC Frogwatch, 1993).

Bullfrogs are native to central and eastern USA and southern Quebec and Ontario (SeaGrant, 2020). They are introduced throughout Metro Vancouver, parts of the Fraser Valley (Zevit, 2019) and on the southern part of Vancouver Island, the Sunshine Coast, as well as some Gulf Islands (Province of BC, 2020). One known introduced population in the Okanagan was eradicated after extensive efforts from 2004-2012 using a variety of methods (Davies, et al., 2020). Efforts are underway to eradicate populations in the West Kootenays near Creston that have come across the border from Idaho State (American Bullfrog Action Team, 2020). Outside of North America, bullfrogs have been introduced to Europe, South American, and Asia (SeaGrant, 2020).

CLIMATE ADAPTATION

Climate modellers predict that the Metro Vancouver region will experience warmer temperatures; a decrease in snowpack; longer dry spells in summer months; more precipitation in autumn, winter and spring; more intense extreme events; and an extended growing season. In the past, our region had an average of 252 days in the growing season. In lower elevations 45 days will be added to the growing season by the 2050s, and 56 days by the 2080s, resulting in nearly a year-round growing season of 357 days on average. In higher elevation ecosystems the growing season length will increase by 50% to 325 days by the 2080s (Metro Vancouver, 2016). These changes will stress many sensitive ecosystems, increasing their vulnerability to invasive species (United States Department of Agriculture, 2021).

It is speculated that this species may benefit from our future climate in several ways:

- Increased precipitation and flooding: Flooding wetlands can improve connectivity and therefore increase bullfrog ability to migrate and expand their range (American Bullfrog Action Team, 2020).
- Warmer temperatures: Bullfrogs can tolerate a wide range of water temperatures (Langley Environmental Partners Society, 2014) and there is a potential for establishment in traditionally cooler, even subalpine environments as temperatures increase. Warm waters allow bullfrog tadpoles to develop more quickly and reduce exposure to predators (United States Department of Agriculture, 2021). Warmer temperatures may reduce winter hibernation periods of bullfrogs, which would afford them a longer reproductive and growing season; however, after high water situations, temperatures may reduce the reproductive window for bullfrogs during the summer months (egg development is impaired in water above 31°C) (United States Department of Agriculture, 2021).
- Summer drought and heat waves: These events could limit bullfrog movements in dry conditions, but are unlikely to increase mortality (United States Department of Agriculture, 2021). Since bullfrogs are primarily nocturnal, they are able to avoid high temperatures during the hottest times of the day. Bullfrogs live many years allowing them to outlive the average expected drought periods (5-7 years) even if breeding is limited during these times (United States Department of Agriculture, 2021).
- Extended growing season: Bullfrogs have a wide annual reproductive period (United States Department of Agriculture, 2021) and bullfrog reproduction is not as dependent on timing changes or cues in the environment as native frogs (United States Department of Agriculture, 2021). Currently in Metro Vancouver, bullfrog females lay eggs once per year, but in other parts of the world with similar growing seasons to what is projected in Metro Vancouver, they are able to reproduce twice per year, which allows populations to expand much more rapidly (Switzer, 2020). Bullfrogs prefer wetlands with thick vegetation and may benefit from an extended growing season for plants.

With these kinds of competitive advantages, this species is more adaptable than native frogs in a variety of ecosystems. Its ability to reproduce successfully and migrate fairly long distances to find new habitat if home ponds are destroyed suggest that bullfrogs will be able to withstand, and possibly thrive, with changing climate conditions.

Identification

Unless otherwise noted, the following identification information was collected from the BC American Bullfrog Alert (Province of BC, 2020) and Bullfrog Factsheet (BC Frogwatch, 1993).

Lifecycle: Like all frogs, bullfrogs go through multiple distinct life stages from egg, tadpole, metamorph, juvenile to adult. Adult bullfrogs gather at breeding ponds in May and June (Metro Vancouver, 2018), much later than most native frog species. Males establish a territory and call loudly to attract females. During mating, females lay eggs on the water's surface. Eggs hatch within four or five days (depending on temperature). Most tadpoles hatch in July and remain in the ponds through that summer and the following winter, metamorphosing in August or September of their second year. They may not reach breeding age for two or more years after metamorphosis. Bullfrogs can survive up to 10 years, but mortality is very heavy in the first few years.

In their native eastern Canada, adult bullfrogs hibernate in breeding ponds during the winter months. In milder British Columbia winters, they may not fully hibernate, but reduce their activity, buried in silt and mud, emerging in the spring. During the winter months, bullfrogs can likely be found 18-53 centimetres below the water or ice surface (Sepulveda & Layhee, 2015).

Egg Masses: Large, loose, jelly-like clusters of up to 20,000 eggs that float on the surface of water (Langley Environmental Partners Society, 2014).

Tadpoles: Dark green to black with creamy white/yellow belly and a large fin on the back with discrete spots, up to 15 centimetres long (much larger than other tadpoles). Bullfrogs often spend up to two years in the tadpole stage, compared to just a few months for many other frog species.

Metamorphs: At this stage between tadpoles and juveniles, legs develop and metamorphs resemble frogs but still have the remnants of a tail.

Juveniles: Green to brown with tiny black spots, orange or bronze eyes, about 10 centimetres long (Langley Environmental Partners Society, 2014).

Adults: Colouration varies from black to dull green/olive to brown in colour on back and sides, creamy white on belly, with dark blotches on the back and legs (SeaGrant, 2020); up to 18-20 centimetres long from nose to the end of the body (not including the legs) and 750 grams in weight; large golden eyes. Bullfrogs have a large and distinct tympanum (plural tympana), a circular hearing organ located just behind and below each eye that is partly surrounded by a skin fold running from the eye down to the shoulder. They lack raised skin folds along the sides of the body (called dorso-lateral folds) which are found on other frogs.

Males are typically smaller than females. Mature males have a bright yellow throat during the breeding season. The male tympanum is roughly twice the size of the eye, while the female tympanum is about the same size as the eye.

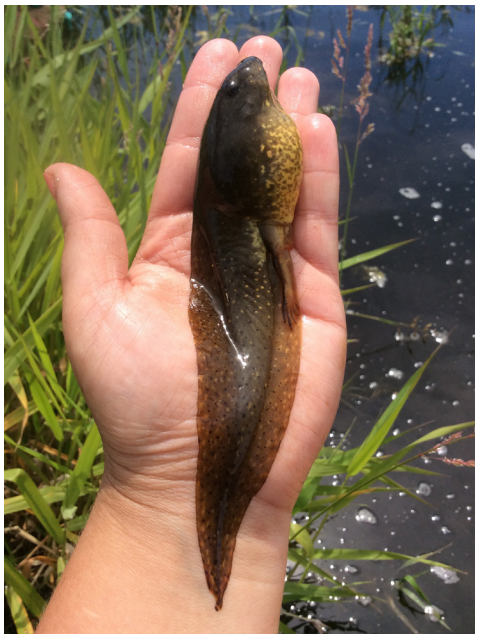
Diet: Tadpoles are primarily herbivorous, grazing on algae and detritus, although they will eat frog eggs, newly hatched tadpoles and insects. Adult American bullfrogs are carnivorous and notorious for eating anything they can catch and swallow; prey includes insects, crustaceans, fish, bats, small invertebrates, birds, small mammals, snakes, turtles, toads and frogs (including smaller bullfrogs) (SeaGrant, 2020). Insects are the predominant food source (Jancowski & Orchard, 2013). American bullfrogs rarely forage on land.

Predators: Snakes, turtles, fish, racoons, and birds will prey on tadpoles and young bullfrogs. Bullfrogs are cannibalistic and adults are likely the main predator of tadpoles and young bullfrogs (SeaGrant, 2020).

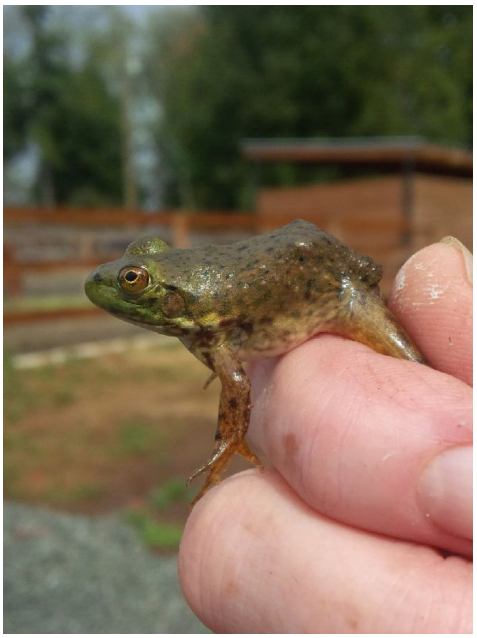
The following photos show American bullfrog in various life stages.

American bullfrog egg mass floating on the water's surface
CREDIT: KENDRA MORGAN

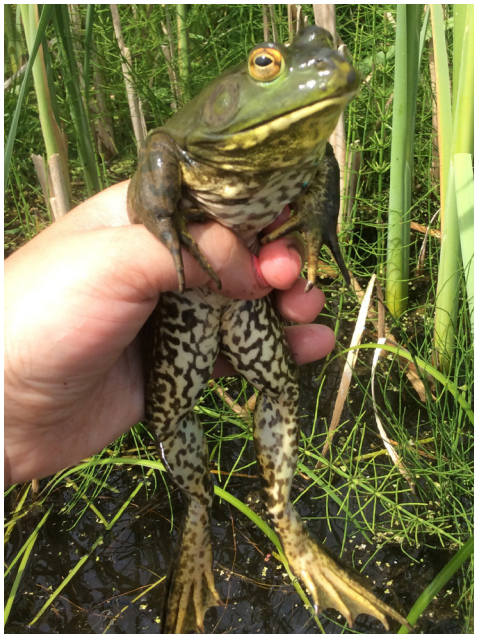
American bullfrog egg mass
CREDIT: KENDRA MORGAN



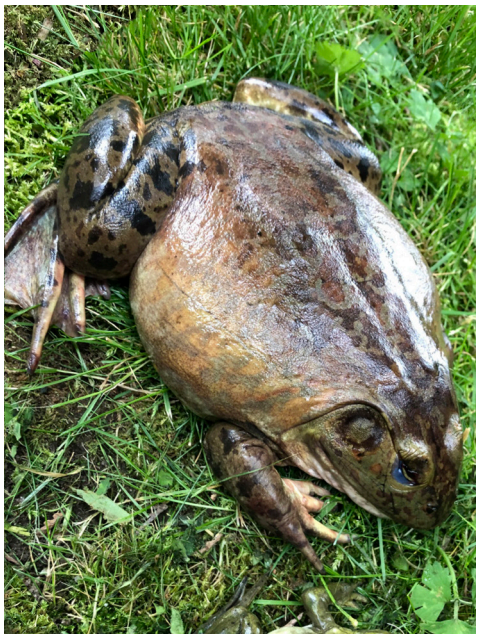
American bullfrog tadpole
CREDIT: ALEESHA SWITZER



Juvenile American bullfrog
CREDIT: FRASER VALLEY CONSERVANCY



Adult American bullfrog
CREDIT: ALEESHA SWITZER



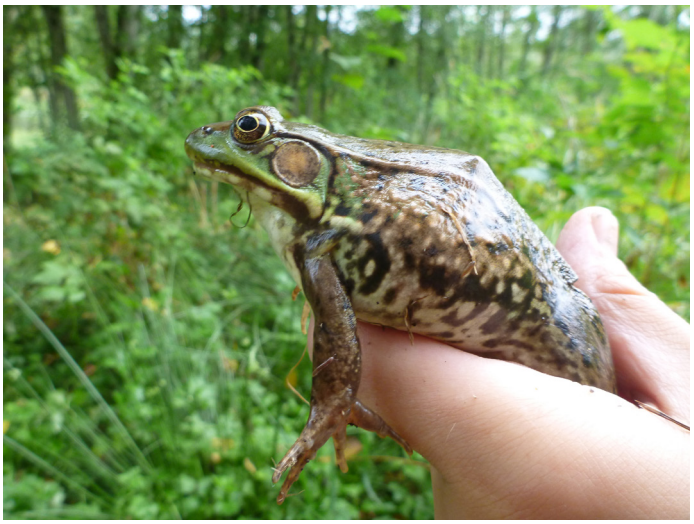
Plump adult female American bullfrog carrying approximately 20,000 eggs
CREDIT: ALEESHA SWITZER

SIMILAR SPECIES

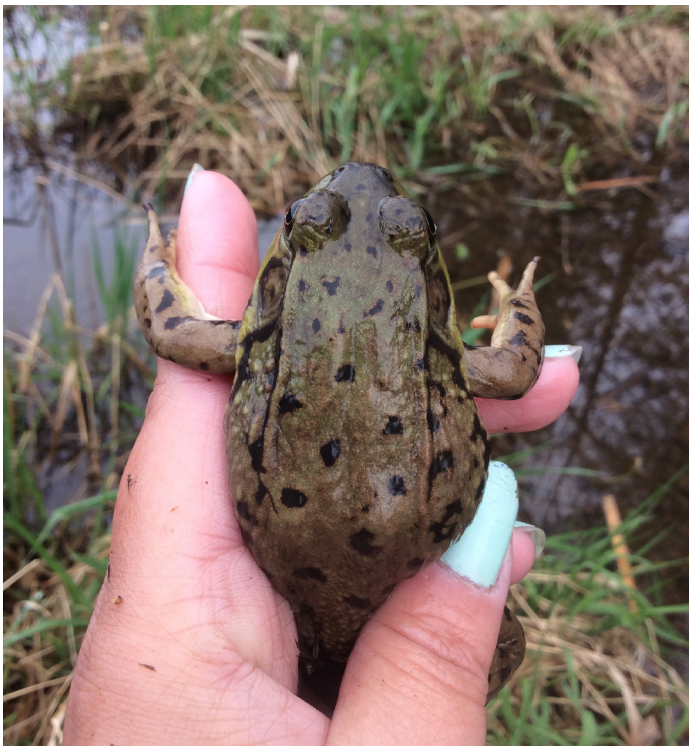
In the Metro Vancouver region, there are several native frog/toad species and one non-native frog that may be confused with bullfrogs. These are described below, with the features that distinguish them most from bullfrogs underscored. American bullfrog is North America's largest frog, and all life stages are generally much larger than those of other frog species. Most other species also lack a prominent tympanum (Metro Vancouver, 2018). Native frogs that live in wetlands and marshes breed in the early-mid spring and bullfrogs breed in the early-late summer (Fraser Valley Conservancy, 2020).

NON-NATIVE SPECIES

- Green frog (*Lithobates clamitans/Rana clamitans*): Most often confused with bullfrogs; also have a conspicuous tympanum, but unlike American bullfrogs, have two dorso-lateral ridges from the eyes and down the back. Green frogs are not as large as bullfrogs, only reaching a maximum of 10 centimetres (Metro Vancouver, 2018). They have a similar range as bullfrogs, found in Metro Vancouver and the Fraser Valley, and expanding eastwards (Zevit, 2019). Like bullfrogs, green frogs are listed under the regional containment/control category on the Provincial Priority Invasive Species list. Green frogs are not considered as deleterious to native species as bullfrogs, and are often a lower priority species for control efforts (Switzer, 2020).



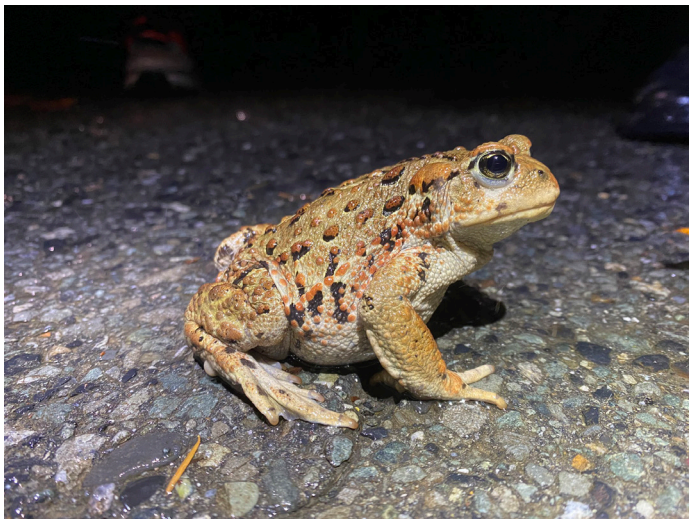
Green frog
CREDIT: FRASER VALLEY CONSERVANCY



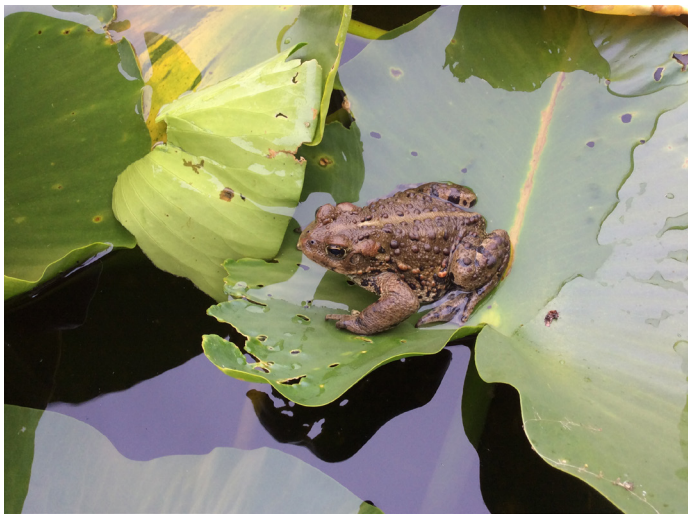
Green frog with dorso-lateral folds visible on the sides of the body
CREDIT: ALEESHA SWITZER

NATIVE SPECIES

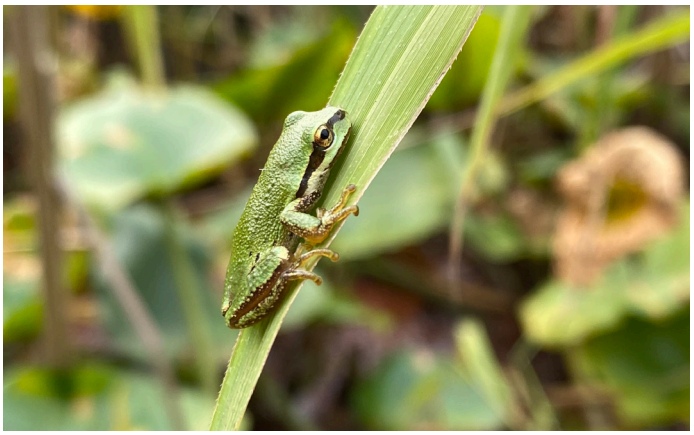
- **Western toad (*Anaxyrus boreas/Bufo boreas*):** At 12-16 centimetres, Western toads can be quite large, and their size alone may cause confusion with bullfrogs (Fraser Valley Conservancy, 2020). They have dry, bumpy, warty skin (Fraser Valley Conservancy, 2020) with a distinctive pale-coloured stripe down the back (Balance Ecological, 2013). Raised parotoid (poison) glands are located on the sides of the head behind the eyes. Like bullfrogs, they lack dorso-lateral folds and adults have visible tympana, but the latter are always smaller than the eye.
- **(Northern) Pacific tree frog/Pacific chorus frog (*Pseudacris regilla*):** Less than 5 centimetres at maturity, pale yellow to bright green to brown body with gold flecks (colouration is dependent on location). Adults have a distinct black stripe from the nose to the forearm (Balance Ecological, 2013). Adhesive toepads are present on all toes (Central Kootenay Invasive Species Society, 2018).
- **(Northern) Red-legged Frog (*Rana aurora*):** 7-10 centimetres in length (BCSPCA, 2018). Smooth, not bumpy, skin on back and legs. Legs are pink-red with gold flecks and bright yellow patches on the sides (Balance Ecological, 2013). Red-legged frogs have a blue-listed conservation status in BC, which means they are of special concern.
- **Oregon spotted frog (*Rana pretiosa*):** Skin colouration ranged from white-grey mottled to bright red on entire body (Balance Ecological, 2013). Raised bumps on the sides and sometimes back. Usually found in a low, crouched position, rather than an upright posture. Oregon spotted frogs are endangered in British Columbia.
- **Tailed frogs (*Ascaphus truei*):** Less then 5 centimeters at maturity. Adults do not have tympana and are usually tan to brown, but vary in colour. Tailed frogs do not have a true tail, rather males have a fleshy appendage that is an extension of the cloaca (South Coast Conservation Program, 2020). Their preferred habitat is mountain streams at high elevation (Balance Ecological, 2013). Tailed frogs are not widespread in Metro Vancouver but have been found in southwest Coquitlam and the North Shore (South Coast Conservation Program, 2020).



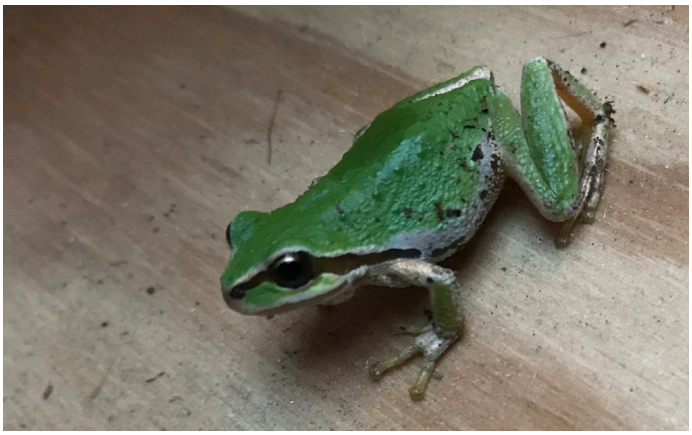
Western toad
CREDIT: JENNIFER BARDEN



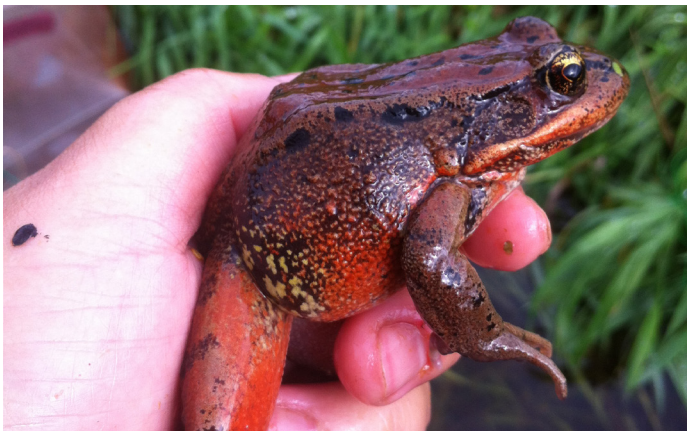
Western toad
CREDIT: JENNIFER BARDEN



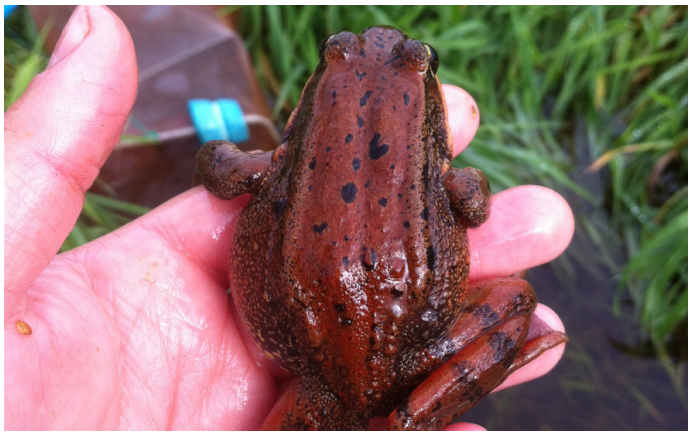
Pacific tree frog/Pacific chorus frog
CREDIT: JENNIFER BARDEN



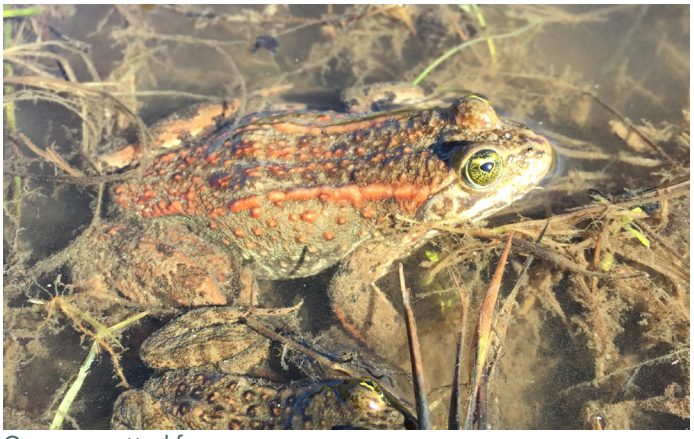
Pacific tree frog/Pacific chorus frog



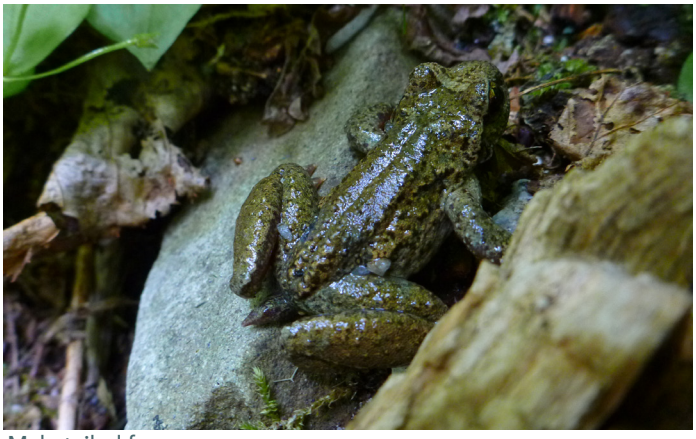
Red-legged frog
CREDIT: ALEESHA SWITZER



Red-legged frog
CREDIT: ALEESHA SWITZER



Oregon spotted frog
CREDIT: ALEESHA SWITZER



Male tailed frog
CREDIT: CHRIS LEE

Tracking

Bullfrogs are more often heard than seen (BC Frogwatch, 1993). During the summer males make loud, deep mating calls that sound like "jug-o-rum" or "br-wum" (Langley Environmental Partners Society, 2014). These calls can be heard up to a kilometre away (BC Frogwatch, 1993). Examples of American bullfrog calls are easily found online.

There are a number of different ways to survey for the presence of bullfrogs in a wetland. Some can be done from shore, but others may require boat access.

- **Visual surveys** can be conducted during the daytime. Adult bullfrogs often float just beneath the water's surface, with only their eyes and green snouts visible (BC Frogwatch, 1993).
- **Spotlight surveys** use a flashlight to detect the frog eye shine in darkness. The light also stuns the frogs temporarily, which is useful for capturing them. Use of spotlight surveys for capturing bullfrogs is described in more detail in the Manual/Mechanical control section. Note that eye shine is difficult to distinguish between species, and all frog species can be spotted using this method (Switzer, 2020).
- **Calling surveys** involve listening for bullfrog sounds in a suspected habitat. Visit a quiet spot (ideally at dusk or later) and wait silently. Record any bullfrog sounds. It is also possible to play bullfrog calls on a recording device to entice bullfrogs to return the calls. One criticism of this method is the risk of encouraging bullfrogs to invade a wetland they didn't already exist in (American Bullfrog Action Team, 2020).
- **Song meters** use acoustic detection to record bullfrog calls from devices installed at sites. This can be used as an early detection method. Analysis requires software to filter out bullfrog calling from other ambient sounds. It can be time time-consuming and requires a technician to collect the sample data from the field and filter it through the software program. Equipment is generally very expensive but alternatives are becoming more widely available (e.g., AudioMoth®) (American Bullfrog Action Team, 2020).
- **Conservation canines**, or detection dogs, can be trained to sniff bullfrogs. Canine surveillance services have been used to detect bullfrogs in the Creston area (American Bullfrog Action Team, 2020).
- **Environmental DNA (eDNA)** is the collection of DNA from environmental samples such as water or soil rather than directly from an animal. This technology has evolved over the last 10 years as a low impact tool to inventory species, however it has limitations in aquatic environments. It can only measure presence or not detected (no detection does not necessarily mean a species is absent from the area, it could be that the sampling didn't detect the target species). It is unknown how close a sample needs to be taken from an individual of the target species to be detected (Morrison, 2021). The method may struggle to confirm presence in low densities and in aquatic systems with high amounts of algae which clog the filters (Morrison, 2021).

  Metro Vancouver's Watershed and Environmental Management department undertook a study in 2017 using this method to determine bullfrog presence within the Capilano Watershed and Lower Seymour Conservation Reserve (Hobbs, 2019). Bullfrog eDNA was detected at a single known breeding site (Elveden Lake) but was not detected at the any other sites tested (Hobbs, 2019).
- **Radio telemetry** uses radio signals from transmitters attached to animals to track their movements. Bullfrogs tracked using this method are fitted with a "belt" or "backpack" (Switzer, 2020). In British Columbia, this method is primarily used to track bullfrog movement

from the United States to Canada (American Bullfrog Action Team, 2020) and to study local habitat selection (Switzer, 2020).

- **Netting and trapping** methods described in the prevention and control strategies section below may also be used as a passive form of detecting bullfrog presence (Morrison, 2021).

When carrying out a bullfrog inventory, the BC FrogWatch program recommends recording the following information (BC FrogWatch, 2020):

- Method of survey (e.g., whether bullfrogs were seen or heard and how);
- Date and time/duration of survey;
- Location/waterbody;
- Type of habitat;
- Air temperature, water temperature, weather conditions;
- Number of animals, eye shines, calls or egg masses observed;
- Life stage, age and sex observed (may not be possible to collect depending on survey method);
- For capture surveys, snout to vent length (SNV) and weight; and
- Photos

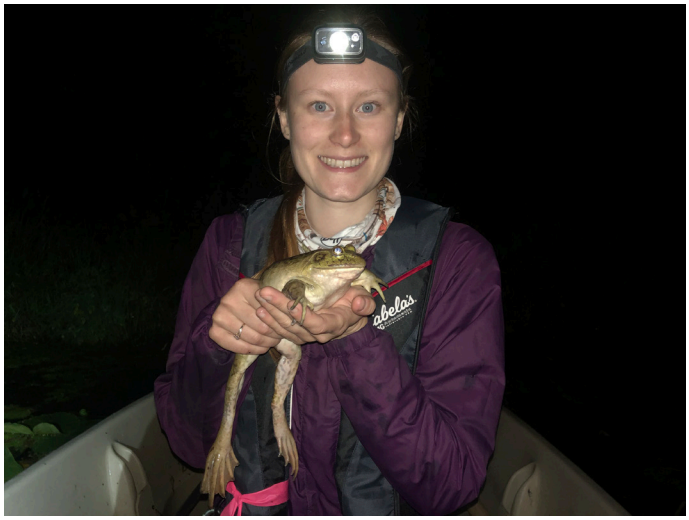
For more information about collecting data on frogs, visit the BC Frogwatching site.

Reporting

American bullfrog is widespread throughout the Metro Vancouver region. In areas where bullfrogs have not previously been detected, or if you are unsure if bullfrogs have been detected, local experts should be alerted immediately (Switzer, 2020). Please report bullfrog occurrences to:

- The Provincial Reporting Invasive Species program (via online form or smartphone app)
- Outside of Metro Vancouver, contact the regional invasive species organization as some areas have active bullfrog control programs.

Reports submitted through these channels are reviewed by specialists who coordinate follow-up activities when necessary with the appropriate local authorities.



Jennifer Barden (Fraser Valley Conservancy) capturing American bullfrog during a nighttime survey
CREDIT: ALEESHA SWITZER

Prevention and Control Strategies

Effective invasive species management may include a variety of control techniques ranging from prevention, chemical, manual, mechanical, biological, and/or cultural methods.

In areas where bullfrogs have not been detected previously, or where control efforts are ongoing, bullfrogs should be captured and, upon identification and confirmation by a species expert, euthanized humanely (Switzer, 2020). Information on euthanasia can be found below. Management activities should prioritize newly established populations to avoid future spread (Zevit, 2019).

Large-scale bullfrog eradication requires a large investment of resources and possibly major environmental alterations, and may not be successful. If bullfrogs are well established in an area, managing at a particular pond may be futile since bullfrogs from adjacent ponds will simply move in and repopulate. Experts agree that bullfrog eradication is cost prohibitive and likely impossible in Metro Vancouver; however, there are provincial efforts on bullfrog control primarily focused on mitigation and education (American Bullfrog Action Team, 2020). If the goal is to increase biodiversity at the site, and not just remove bullfrogs, then control may be justified (Switzer, 2020). The Restoration section provides additional information.

Since bullfrogs travel easily, success involves partnership with all adjacent land managers that have ponds or suitable habitat within a five kilometre radius of the site (Switzer, 2020). The American Bullfrog Action Team is a collaboration of representatives from across British Columbia, Idaho and Washington states, developing regional early-detection and rapid-response plans for bullfrogs in other regions (American Bullfrog Action Team, 2020).

One of the biggest barriers to bullfrog management is site access. Since bullfrogs live primarily in wetlands, management activities may require the use of waders or boats (kayak, canoe, etc.). For safety, it is recommended to always conduct activities in pairs. Some of the methods outlined below may be more difficult by boat.

Under the *BC Wildlife Act*, bullfrogs are not candidates for wildlife rehabilitation or release. If a bullfrog is found or surrendered, it should be humanely euthanized using the techniques outlined below.

STRATEGY COLOUR LEGEND

GREEN: RECOMMENDED

ORANGE: CAUTION

RED: NOT RECOMMENDED OR NOT AVAILABLE

PREVENTION: IMPERATIVE

Prevention is the most economical and effective way to reduce the spread of American bullfrog over the long term.

The following prevention measures are required in BC (Province of BC, 2020):

- Do not collect, possess, breed, ship or release American bullfrogs;
- Do not collect and/or transfer tadpoles of any kind; and
- Do not stock ponds with purchased aquarium frog species.

Outreach is another major component of bullfrog management. It is important that adjacent land managers (including private property owners), and the public are educated about management efforts in an area and understand preventative measures. Stewardship groups around British Columbia play a significant role in reporting bullfrogs, supporting control efforts, monitoring sites and providing education (American Bullfrog Action Team, 2020). Schools and other organizations have been documented as a pathway of spread for non-native frogs and other species in British Columbia, so engaging "formal and informal educators and citizen science groups is essential" (Zevit, 2019).

MANUAL/MECHANICAL: RECOMMENDED

Various manual/mechanical control techniques are available in British Columbia to capture and euthanize bullfrogs. It is imperative to confirm identification prior to undertaking bullfrog management, especially before capture or euthanasia.

American Bullfrog is listed in Schedule C of the *BC Wildlife Act* and *Wildlife Act Designation and Exemption Regulation* which lists wildlife species that can be captured or killed just about anywhere and at any time in British Columbia (permission from land owners on private land, including cultivated land which is subject of a grazing lease, is required). A hunting licence is not needed to hunt or kill Schedule C wildlife; however, other regulations must be abided by (e.g., no shooting or hunting zone, no shooting across a highway, prohibited hours, motor vehicle closed areas). Before managing bullfrogs, check local bylaws and/or regulations to confirm whether chosen capture and control methods are permitted for use at the intended site (BCSPCA, 2018). It is an offence under the *Wildlife Act* to traffic wildlife, live or dead, without proper authorization; Schedule C wildlife is not exempt. More information on Schedule C wildlife can be found in the Hunting & Trapping Regulations Synopsis.

The following methods of capture are from the American Bullfrog Action Team (2019 & 2020), Fraser Valley Conservancy (2020), Switzer (2020), and Ministry of Forests, Lands and Natural Resource Operations (2016). Some methods are lethal (noted with *); non-lethal methods of capture require humane euthanasia afterwards (see below). Multiple methods may be used at a site in order to target multiple life stages and increase efficiency (Quinn, Wilson, Brown, & Naumann, 2010). These methods can be followed up with a cultural control method and restoration to enhance habitat for native species. **Note that trapping requires permits, as do any activities that may involve handling native wildlife (permits are available from FrontCounterBC).**

Equipment for many of the methods described below can be purchased from biological equipment supply companies, however, practitioners often have success custom-making or adapting tools and traps (BC Ministry of Environment, 2011).

AMERICAN BULLFROG MANUAL/MECHANICAL CAPTURE AND CONTROL METHODS

CONTROL METHOD*	SUITABLE LIFE STAGE	PROS	CONS+	COMMENTS/TIPS
Remove egg masses using a fine net or bilge pump every 2-3 days*	Eggs (from late-May to early September)	Easiest life stage to control, considered a humane method (Langley Environmental Partners Society, 2014)	Need to consistently monitor site every 2-3 days since eggs can develop into tadpoles in less than 5 days during warm weather, eggs can be missed, will take 3-4 years to see results	Do not remove any egg masses in the spring as those belong to native frog and salamander eggs, place egg masses on land to dry out or bury them to avoid odours (Langley Environmental Partners Society, 2014)
Dip nets allow the scooping of bullfrogs near the water's surface	Tadpoles, juveniles, adults	Equipment easy to source, doesn't require submerging hands into the water and therefore suitable in cold temperatures	Risk of bycatch, capture success improves with experience	Success depends on size of tadpoles/juveniles, population density, and habitat conditions, use good quality nets
Hand capture adults by shining a bright flashlight beam on the surface of the water; once you see the eye shine, keep the beam steady on the eyes of the frog to stun it; slowly approach and capture by hand, net or bucket	Juveniles, adults during breeding season (mid-May to August)	No specialised equipment needed	Need to get within close proximity to the target, capture success improves with experience, risk of bycatch, ineffective in complex habitats with woody debris or tall vegetation, bullfrogs are harder to catch if missed on the first attempt	Track bullfrogs by sounds (described above), wear gloves
Use a **paddle whapper** (modified axe handle with a piece of plywood attached at the end) to strike and stun frogs to render them unconscious	Adults, juveniles	Inexpensive, light to transport, no specialised training required, easier than hand capture as you don't need to be as close to the target	Risk of bycatch, may be difficult to retrieve in ponds with a lot of vegetation, capture success improves with experience, bullfrogs are harder to catch target if missed on the first attempt	Success higher than hand capture, use eye shine tracking method as described for hand capture method
Fyke or hoop nets (cylindrical, collapsible traps with a funnel at one end)	Metamorphs, juveniles, adults, (sites with high densities of bullfrogs)	Simple to deploy	High risk of bycatch, difficult to set up, low efficacy	Use with or without bait, partially submerge funnel opening to optimize capture

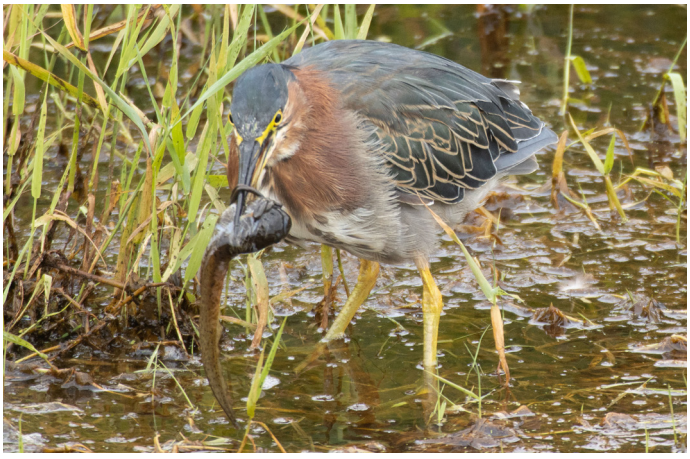
CONTROL METHOD*	SUITABLE LIFE STAGE	PROS	CONS+	COMMENTS/TIPS
Traditional electro-fisher (a direct current in the water that causes effected frogs to move towards the anode probe, allowing capture)	All life stages except eggs	Not harmful or lethal for bycatch	Certification/training required, at least two people are needed – one to operate the anode and the other to catch the stunned frog with a dip net, risk of bycatch, specialised training or crews required (at least 2 people), heavy and awkward to transport, unsafe to use from a boat unless it is adapted for this use, expensive	Other methods described above are just as effective
Electro-frogger (a British Columbia-adapted electro-fishing device designed to paralyze bullfrogs using a two-metre pole delivers an electric charge into a small area of water) (Jancowski & Orchard, 2013)	Adults, juveniles (works best on adults)	Non-invasive and non-lethal for bycatch, more effective than traditional electro-fisher	Specialised training or crews required (at least 2 people), capture success improves with experience, difficult to use in heavy vegetation and shallow water, equipment not currently available (inventor is seeking a manufacturing permit)	Once targets are shocked, they sink, so need to catch quickly
Minnow traps are rectangular or circular traps with openings on either end that guide frogs into the trap	All life stages except egg masses (large adults may also not fit in the trap openings)	Simple to deploy, easy to source	High risk of bycatch, must check trap daily, poor effort/capture ratio	Fencing set up along migratory routes or stream flows can be used to direct targets into traps, use with or without bait, partially submerge funnel openings to optimize capture
Pitfall or funnel traps capture frogs moving from one site to another; **basking traps** are floating pitfall traps, with a basking perch on the top of the trap that attracts bullfrogs	Juveniles, adults	Easy to source	High risk of bycatch, high installation effort, may require barrier fencing to guide targets into the traps, must check trap daily, poor effort/capture ratio	Traps should have perforated bottoms so they don't accumulate water, may need to consider a cover so frogs can't jump out once caught
Seine nets (weighted nets suspended across a water body and surveyors at each end slowly move towards each other forming an arc to trap bullfrogs inside) can be used to sample a large area in a short period of time	All life stages (except eggs) in isolated water bodies (not suitable for large or deep water bodies or ones that have woody debris, trees, or dense vegetation)	Alternative to traps	Risk of bycatch, escape underneath the net possible, requires a crew of a few people to maneuver the net, poor effort/capture ratio	Use a mesh size suitable to capture target life stages

CONTROL METHOD*	SUITABLE LIFE STAGE	PROS	CONS+	COMMENTS/TIPS
Pellet rifle of at least a 22-caliber is needed to be lethal (non-PAL rifles don't have enough power)*	Juveniles and adults (daytime shooting effective for juveniles that bask on water surface and are easy targets)	Can shoot from a distance or locations difficult to access, effective for skittish targets that do not respond to other methods	Firearm use is restricted in urban areas, PAL required, capture success improves with experience, lethal risk to non-targets, may not be fatal and cause unintended suffering, difficult to retrieve target if shot at distance, risk of pellet leach into water	Very few pellets remain in the targets, so need to consider fate of the pellets (lead pellets are most effective but can leach into the environment; ammunition alternatives include aluminum alloy and steel), use as a secondary method after others prove ineffective

*Only removal of egg masses and the pellet rifle are intended to be lethal. Other methods are either not lethal, or may be lethal. Non-lethal methods of capture require humane euthanasia afterwards (see below).

+For methods with a risk of bycatch, a permit must be acquired due to the risk of catching other wetland species.

** Possession and Acquisition License (PAL)



Green heron with an American bullfrog tadpole
CREDIT: COLIN CLASEN

TIMING

Target adults starting in mid-May to prevent egg laying (SeaGrant, 2020). Capture methods will be more successful later in the summer when temperatures are warmer and bullfrogs are sitting at the surface of the water (Switzer, 2020).

Reducing bullfrog numbers at all life stages can support native species in natural areas when part of a larger habitat enhancement plan (Fraser Valley Conservancy, 2020). Govindarajulu et al (2005) modelled demographic data to determine the best bullfrog life stage to target in management efforts. **Targeting egg masses in the spring and metamorphs in the fall will have the most success decreasing bullfrog population growth rates.** Programs that only target adults increase survivorship of metamorphs through reduced cannibalism (Govindarajulu, Altwegg, & Anhold, 2005). Partial removal of tadpoles may lead to higher tadpole survival due to decreased competition (Govindarajulu, Altwegg, & Anhold, 2005). Since management of particular life stages can actually promote population growth, it is imperative that management efforts be well-planned and not simply a reactionary response to bullfrogs being present in an area.

Bird nests (ground and in trees), salamanders, and other wildlife may be present at wetland sites. If working during bird nesting season, the site should be inspected by a qualified environmental professional.

APPLYING MANUAL/MECHANICAL CONTROL METHODS IN RIPARIAN AREAS

American bullfrogs live in wetlands. Consider the impact of control techniques on the aquatic environment. Schedule removal works during a period of least risk to fish species, outside of the fish window. Adhere to provincial and federal riparian regulations. It is recommended to consult with a qualified environmental professional when working around water bodies.

EUTHANASIA

For manual control methods that involve capture only, or when the target is injured but not killed, bullfrogs must be humanely euthanized, which ensures rapid brain death without pain (Schwantje & Govindarajulu, 2020). The following humane, cost effective, and easy to use method is recommended (Schwantje & Govindarajulu, 2020) (American Veterinary Medical Association, 2020):

1. Induce a deep level of anaesthesia using the readily available over-the-counter chemical **Orajel®** (active ingredient benzocaine), used is an ointment used to relieve toothaches in humans. It can be squeezed on the finger and spread generously over the back, tummy or legs of the frog. Alternatively, make a 1% benzocaine solution and immerse the frog.
2. Both chemicals will induce anaesthesia in frogs in about 15-30 minutes. There are two methods to test the level of anaesthesia:

    a. Place the frog on its back – if the frog doesn't respond and turn over within one minute, it is deeply anaesthetized.

    b. Pinch the frog's toes – if the leg does not retract, it is deeply anaesthetized.

    Reapply Orajel® if the animal does not reach deep anaesthesia with the first application.

3. Once the frog is deeply anaesthetized, it can be decapitated or placed in the freezer (for at least a day) to complete euthanasia. This should be completed as soon as the frog is in deep anesthesia as it can revive quickly.

The following methods of euthanasia are illegal: carbon dioxide/carbon monoxide, decapitation (without prior anesthesia), immersion in alcohol or Alka-Seltzer solution, freezing (without prior anesthesia), inhalant anesthetics, pithing (without prior anesthesia) and poison (BCSPCA, 2018).

CULTURAL: RECOMMENDED

Cultural control methods described below can be implemented after manual/mechanical control methods have been used to reduce bullfrog populations at a site. Bullfrogs have the ability to seek new sites to feed or breed, while native species do not have the same adaptability or ability to migrate (Switzer, 2020). Cultural control methods should promote management of sites for native species survival, rather than bullfrog preference (Switzer, 2020).

- Habitat manipulation of wetlands to create suitable habitat for native frog species and to deter bullfrog inhabitance has been used across British Columbia. Land owners with ponds can create a more attractive environment for native frog species to live in (Province of BC, 2020).

Restoration efforts should be focussed on the areas where water collects or where native amphibians are observed (Fraser Valley Conservancy, 2020). Plant native species around ponds to provide shade and decrease temperature, which discourages bullfrogs (see Restoration section for more information) (Langley Environmental Partners Society, 2014). Debris and complexity are critical for aquatic invertebrates and serve as hiding places for native amphibians (Switzer, 2020). Enhance existing features of a site before creating something new (Fraser Valley Conservancy, 2020). Avoid creating artificial wetlands that consist of deep ponds with year-round water (Zevit, 2019).

- Water level management to create temporary or ephemeral pools can limit bullfrog breeding and tadpole survival (American Bullfrog Action Team, 2019). Early life stages of native frogs only require about three months of water (Fraser Valley Conservancy, 2020), but bullfrogs require permanent waterbodies for at least 2 years until reaching maturity, and cannot survive in dry conditions (SeaGrant, 2020). A qualified environmental professional should oversee and monitor this work, which may require special permits and should include analysis of impacts to other amphibians, fish or other species present at the site (Switzer, 2020),

  The best time to draw water down to deter bullfrogs is the end of the summer, after native species have metamorphosed (Fraser Valley Conservancy, 2020). If water levels are managed for other purposes, time changes to coincide with bullfrog management. This method can work in combination with manual bullfrog control methods that target all life stages at a site (Quinn, Wilson, Brown, & Naumann, 2010)

- Containment of bullfrogs can intercept access to new locations, but is often not feasible due to the large areas that would require fencing and monitoring (American Bullfrog Action Team, 2019). Fences may be installed at sites to create barriers where bullfrog distribution and travel corridors are known (BC Ministry of Environment, 2011). This method should only be undertaken as part of a long-term management plan, which includes at least one full year of spring, summer and fall surveys to detect other species in the area that may be restricted by fencing (Switzer, 2020).

  Fences can be made of many materials, including plywood, sheet metal, building wrap, silt fencing, and hay bales (Ministry of Forests, Lands and Natural Resource Operations, 2016). Bury the fence in the ground or leave a lip at the bottom.

- Human consumption of bullfrogs will eliminate some individuals from the environment but it is not a viable management solution at the landscape level. Bullfrogs were originally introduced as a food source in British Columbia, but never became popular. Due to the high probability of misidentification by the public, the potential for transport and escape of live animals into new areas, and the disproportionate removal of larger adults for meat which influences population dynamics, this is not a recommended management solution for Metro Vancouver (Switzer, 2020).

CHEMICAL: NOT AVAILABLE

There are currently no chemical control options available in British Columbia for the management of American bullfrog.

BIOLOGICAL: NOT AVAILABLE

There are no biological control agents currently available in British Columbia for American bullfrog.

CONTROL SUMMARY

The following table provides a summary and comparison of control methods for American bullfrog.

CONTROL STRATEGY	TECHNIQUES	SUITABLE LIFE STAGE	PROS	CONS
Manual	**Remove egg masses**	Eggs (from late-May to early September)	Selective, easiest life stage to control	Need to consistently monitor site every 2-3 days
	Dip nets	Tadpoles, juveniles, adults	Inexpensive	Non-selective
	Hand capture	Juveniles, adults during breeding season (mid-May to August)	Inexpensive, selective	Need to get within close proximity to target
Cultural	**Habitat manipulation**	All life stages	Enhances habitat for native species	Long-term commitment, not possible for all sites
Manual	**Paddle whapper**	Adults, juveniles	Inexpensive, selective, high success rate	Not recommended by the BCSPCA and may be illegal in some municipalities, need to get within close proximity to target
	Fyke nets	Metamorphs, juveniles, adults; sites with high densities of bullfrogs	Simple to deploy	Non-selective
Mechanical	**Traditional electro-fisher**	All life stages except eggs	Non-invasive and non-lethal for bycatch	Expensive, specialized training required
	Electro-frogger	Adults, juveniles (works best on adults)	Non-invasive and non-lethal for bycatch	Equipment not currently available, specialized training required
Cultural	**Water level management**	All life stages	Enhances habitat for native species	Non-selective and can affect other species, not possible for all sites
	Containment	All life stages	Prevents movement of bullfrogs to new locations	Non-selective, requires management of a large area, not possible at all sites

CONTROL STRATEGY	TECHNIQUES	SUITABLE LIFE STAGE	PROS	CONS
Manual	**Minnow traps, pitfall traps**	Juveniles, adults	Easy to source	Non-selective, installation and monitoring efforts high, may require directional fencing
	Seine nets	All life stages (except eggs) in isolated water bodies with few obstacles	Alternative to traps	Non-selective, requires a crew
	Pellet rifle	Juveniles, adults	Can be done from a distance	Restricted in urban areas, firearms license required, may be non-lethal, may be lethal to non-targets, risk of contamination if lead pellets used
Cultural	**Human consumption**	Adults	Food source for humans	Risk of spread and release, not effective as a population control
Chemical	**No chemical control options available in British Columbia**			
Biological	**No biological control agents are currently available for distribution in British Columbia**			

CONTROL SUMMARY COLOUR LEGEND

GREEN: RECOMMENDED

ORANGE: CAUTION

RED: NOT RECOMMENDED OR NOT AVAILABLE

Disposal

Bullfrog bodies can be disposed by composting them in green waste (with kitchen scraps) or in domestic garbage (Schwantje & Govindarajulu, 2020). Large amounts can be buried (Schwantje, 2021), or disposed in landfills, but please contact facilities beforehand to confirm they can properly handle the material (Morrison, 2021). If carcasses are intact, they may be useful to biology classes (Morrison, 2021). Consider contacting local education institutions to see if donations are accepted (carcasses may have to be specially preserved for this use).

When working on bullfrog management activities, due to the risk of spread of frogs, frog spawn, and frog diseases, it is important to implement a cleaning and disinfection regimen (BC Frogwatch, 1993).

CLEANING AND DISINFECTION

Due to the risk of emerging infectious diseases such as the amphibian chytrid fungus that have been implicated in the decline of amphibian populations around the world, and the risk of field staff as potential vectors of these diseases, the Province of British Columbia has established Interim Hygiene Protocols for Amphibian field staff and researchers. It is recommended that all field staff sampling amphibians in wetland habitats incorporate this hygiene protocol into their research plans as standard operating procedure (Province of BC, Ecosystems Branch, Ministry of Environment). Virkon™ is a popular sanitizing solution that is low risk to the environment and less damaging on gear than bleach (Morrison, 2021).

Before leaving a site, all visible plant and animal parts and soil from vehicles, equipment, and gear should be removed and rinsed if possible. When back at a works yard or wash station, vehicles should be cleaned and disinfected using the following steps:

- Wash with 180 °F water at 6 gpm, 2000 psi*, with a contact time of ≥ 10 seconds on all surfaces to remove dirt and organic matter such as vegetation parts or seeds. Pay special attention to undercarriages, chassis, wheel-wells, radiators, grills, tracks, buckets, chip-boxes, blades, and flail-mowing chains.
- Use compressed air to remove vegetation from grills and radiators.
- Sweep/vacuum interior of vehicles paying special attention to floor mats, pedals, and seats.
- Steam clean poor access areas (e.g., inside trailer tubes) – 200 psi @ 300 °F.
- Fully rinse detergent residue from equipment prior to leaving facility.

* Appropriate self-serve and mobile hot power-wash companies in the Metro Vancouver area include: Omega Power Washing, Eco Klean Truck Wash, RG Truck Wash, Ravens Mobile Pressure Washing, Hydrotech Powerwashing, Platinum Pressure Washing Inc, and Alblaster Pressure Washing.

[2] Adapted from Metro Vancouver 2017 Water Services Equipment Cleaning Procedures and Inspection Protocols.

Follow-Up Monitoring

At sites where bullfrogs are presumed eradicated, re-infestation is the biggest threat (American Bullfrog Action Team, 2020). Monitoring should occur every year or two (Switzer, 2020). Song meters can be used to monitor these locations. Any historic bullfrog sites and areas of conservation importance, such as locations with species at risk, should also be monitored (Switzer, 2020).

For sites that are under active control, monitoring should be ongoing and a regular part of the control program. If intense control occurs for one year but not the next, 3-5 years later the bullfrog population may be the same or higher than when the project started (Switzer, 2020).

Suitable wetland habitats where bullfrogs are not yet present, but have the potential to invade, should also be monitored regularly.

Restoration

If the management area contains species at risk, the appropriate recovery team must be contacted first as efforts to control bullfrogs may unknowingly damage important ecological features for the at-risk species (Switzer, 2020).

The Cultural control section also outlines habitat manipulation activities that should be considered during the restoration phase of a bullfrog management plan. Restoration efforts should focus on establishing habitat that is attractive to native species, including invertebrates (Switzer, 2020). The more diversity at a site, the better the habitat for preferred native amphibians. Maintaining or installing a variety of native aquatic or water-tolerant plants, rocks, and large woody debris can add complexity to wetlands (Fraser Valley Conservancy, 2020). When possible, it is best to create connecting habitat between the site and other wetlands or forest ecosystems. Many native amphibians require larger corridors of healthy habitat (Fraser Valley Conservancy, 2020).

Jericho Duck Pond, a prime habitat for the American Bullfrog

An important component of site restoration is the establishment of native plants, which may require management of invasive plants, such as yellow flag iris (Fraser Valley Conservancy, 2020). Site conditions should dictate the need for active restoration. Examples of common competitive native plants prescribed for sites within Metro Vancouver are summarized in the table below (with input from Switzer (2020)).

Replacement species should be chosen based on the ecology of the site by a qualified environmental professional. Local biologists, environmental professionals, agronomists, agrologists, native and domestic forage specialists, seed companies, and plant nurseries are all good sources for localized recommendations for regional native species. Several science-based resources are available to guide restoration efforts, such as the South Coast Conservation Program's Diversity by Design restoration planning toolkit.

WET SITES	MOIST SITES	AQUATIC PLANTS
SHRUBS		Bull rush
Salmonberry	Salmonberry	Cattail
Hardhack	Willow	Floating-leaved pondweed
Willow	Red osier dogwood	Yellow pond lily
Red osier dogwood	Red elderberry	White water-buttercup
Pacific ninebark	Vine maple	Robbin's pondweed
Sword fern	Indian plum	Common rush (*Juncus effusus*)
Deer fern	Sword fern	Slough sedge (*Carex obnupta*)
TREES		Dense sedge (*Carex densa*)
Western red cedar	Western red cedar	Scirpus acutus
Red alder	Red alder	
Sitka spruce		

Restoration sites are often found in areas with existing, or potential, wildlife populations that can damage restoration plantings (deer, beaver, muskrat, vole, etc.). Therefore, any revegetation plan must consider impacts from wildlife and utilize appropriate mitigation measures to protect the restoration and existing native plantings (tree wrapping, exclusion caging/fencing, vole guards, etc.)

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Additional Resources

For more information please refer to the following resources.

- BC FrogWatch program. https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-conservation/amphibians-reptiles/frogwatching
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- Fraser Valley Conservancy. Frogs and Toads of BC's South Coast http://www.sccp.ca/sites/default/files/resources/documents/Frogs%20%26%20Toads%20of%20the%20South%20Coast%20ID%20and%20egg%20mass%20key%20low%20res.pdf
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