Take it to the Ribbit Northern Leopard Frog

ADAPTATION ENVIRONMENTAL SERVICES

A QUEST FOR THE NORTHERN LEOPARD FROG

Take it to the Ribbit

by Adaptation Environmental Services

Project Background

The Northern Leopard Frog (NLF) (*Lithobates pipiens*) has experienced population declines throughout the global range (Hecnar and M'Closkey 1996) but especially in the American Southwest (Rorabaugh 2005). In Colorado, this once-common amphibian has disappeared from many areas where it was once abundant and is listed as a Tier 1 Species of Greatest Conservation Need (CPW 2015). In some areas in Colorado, Northern Leopard Frog extirpations have been linked to the increasing abundance of the invasive American Bullfrog (*Lithobates catesbeianus*) (Hammerson 1982).

The Northern Leopard Frog is strongly associated with temporary or permanent open-canopy ponds and grasslands (Walker 1967; Werner and Glennemeier 1999; Houlahan and Findlay 2003; Rorabaugh 2005; Pillsbury and Miller 2008). In Colorado, this species favors wet meadows and the banks and shallows of marshes, ponds, glacial kettle ponds, beaver ponds, lakes, reservoirs, streams, and irrigation ditches (Hammerson 1999).

Adult and juvenile Northern Leopard Frogs will forage in meadows, fields, golf courses, and some agricultural habitats, demonstrating some tolerance to habitat degradation (Klugh 1922; Zenisek 1963; Gilbert et al. 1994; Rorabaugh 2005; Kapfer et al. 2008; Blomquist and Hunter 2009).

IN THIS ISSUE

FROG WATCH USA

Project Objectives

- To determine the presence/ absence of Northern Leopard Frogs and American Bullfrogs at ponds within three - seven Parks & Recreation properties,
    - (NOTE: 10 properties were visited)
- To determine whether reproduction of either species is occurring, and identify habitat features important for occupancy and reproduction
- To create a comprehensive list of other amphibian species also using ponds on Parks & Recreation lands

Northern Leopard Frog. Photo by A. DuBois

Methods

A total of 10 sites were chosen by City of Boulder Parks and Recreation staff to determine Northern Leopard Frog presence or absence (Appendix A). All other herptile species found were also recorded. Common and scientific names of reptile and amphibian species follow Crother (2017).

This study aimed to target daily and seasonal activity patterns of local amphibian movement.

Evenings of and/ or after rain are better times for detecting amphibian activity. With limited rain-events on CO's Front Range, we made every effort to visit Boulder Parks & Recreation properties within the first 72-hours of significant rain (i.e. rain where the ground has been somewhat soaked and puddles form in roads and/ or at low spots on land). This occurred at least once every 2-week period upon the project's start

Coot Lake Wetlands

To best detect Northern Leopard Frogs four different sampling techniques were used throughout the amphibian breeding window (Hammerson 1999): auditory surveys, visual encounter surveys, road surveys, and funnel trapping.

AUDITORY SURVEYS

Auditory Surveys have been successfully used to monitor amphibian populations in many states and are widely accepted for inventorying purposes. Auditory surveys are particularly useful for identifying presence or absence, as in this study. One limitation to this survey technique is that not all anuran species are equally detectable (Graeter et al. 2013). Protocols for monitoring frogs by call were taken from the citizen-science program FrogWatch USA (AZA, 2016). We also listened opportunistically for calls while we drove near and/ or hiked at properties.

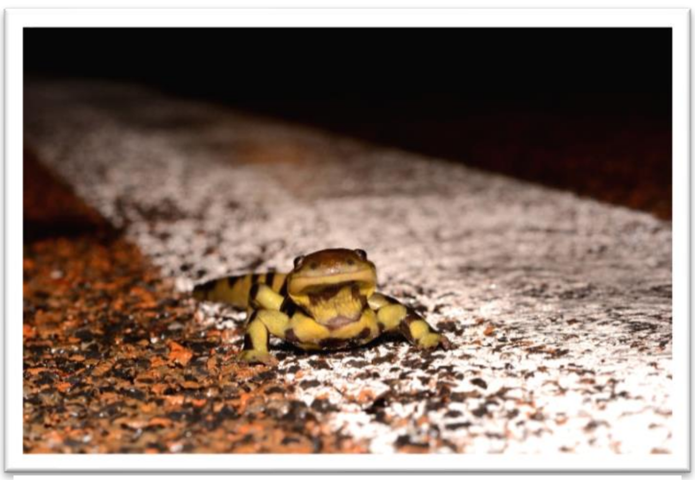
VISUAL ENCOUNTER SURVEYS

Our visual encounter surveys were conducted during each site visit. The shoreline at each site was scanned for egg masses, swimming or basking individuals and dip-netted to locate tadpoles. We collected data on all life stages of encountered herpetofauna in order to assess yearly productivity. We also noted observations of predatory fish species.

Field survey efforts

ROAD SURVEYS

Roads were driven near or adjacent to sites to look for animals crossing roads or nearby pathways. Road surveys are more effective when a road immediately bisects amphibian habitat, such as a body of water. The roads surveyed in this study were all adjacent to the study sites and surveyed immediately after a rain event and in the evening, as Northern Leopard Frogs are most active at night (Harding 1997). All reptile and amphibian observations were recorded.



Barred Tiger Salamander on Road photo by A. DuBois

FUNNEL TRAPPING

Funnel trapping is considered one of the most effective sampling methods for capturing reptiles and amphibians (Graeter et al. 2013). Trapping is beneficial because it is standardized and observer bias is minimized. In order to detect larval amphibians, plastic funnel traps were deployed in the shallow edges of water bodies and checked the following day for captured animals (Adams et al. 1997). Traps were set with ¼ of the trap above the surface of the water to allow captured animals access to air (Graeter et al. 2013). Traps were secured to prevent loss by tying securely or staking near shore. Neon flagging was affixed to assist in locating traps. To maximize captures, traps were set along shorelines, submerged logs, or other obstructions to guide animals into traps (Fitch 1987). All traps were pulled by mid-day the following day after being set to reduce mortality and over-heating of captured animals.

Funnel traps at Admiral A. Burke Park

Results

A total of 10 City of Boulder Parks and Rec sites were surveyed from April to July 2017 for Northern Leopard Frogs. The City of Boulder Parks and Recreation staff selected sites based on observations within the past five years of Northern Leopard Frogs or their egg masses or potential habitat for the species.

In total, 41.6 effort hours were spent conducting auditory surveys, 28.5 effort hours were spent performing visual encounter surveys, 3.5 hours were spent road cruising and funnel traps were deployed for 169 trap-nights.

In total 188 individuals, including eleven species of reptiles and amphibians were recorded, but we did not detect Northern Leopard Frogs (Table 1 and Table 2). To calculate auditory surveys, each calling intensity was recorded as one observation, even if there was a higher calling intensity. Therefore, our total numbers are a conservative estimate.

Table 1. Total number of each individual by species recorded during the survey effort at all combined sites.

Scientific Name	Common Name	Total
Ambystoma mavortium	Tiger Salamander	23
Anaxyrus woodhousii	Woodhouse's Toad	41
Chelydra serpentina	Common Snapping Turtle	1
Chrysemys picta	Painted Turtle	1
Crotalus viridis	Prairie Rattlesnake	3
Lithobates catesbeianus	Am. Bullfrog	25
Lithobates pipiens	N. Leopard Frog	0
Pituophis catenifer	Bullsnake	1
Pseudacris maculata	Boreal chorus frog	81
Thamnophis radix	Plains Gartersnake	3
Trachemys scripta	Red-eared Slider	2
Thamnophis sirtalis	Red-sided Gartersnake	8
	Total	**188**

Call intensity can be used as a measure of relative abundance, but as this is the only year for which we have data, we cannot identify positive or negative trends in abundance. Detectability of these species is not equal and different techniques are more likely to detect one species or life stage more than another. For example, the techniques selected for this study were selected to focus on frogs and not turtles. Therefore, the small number of turtles we detected, or the lack of detection of turtles at some properties, should be interpreted with caution.

A SGCN species (Tier 2) was documented by City of Boulder Parks & Recreation staff in several areas around the Boulder Reservoir, the Red-sided Gartersnake (*Thamnophis sirtalis parietalis*) (J. Wold, pers. Comm).

Area III had the highest richness of species, n = 5. Coot Lake had the second highest richness of species n = 4 (Figure 1). No reptile or amphibian species were located at Admiral Arleigh A. Burke Park, Eaton Park or Pleasant View Fields.

Looking for more on invasive species?

See: Discussion Section Page 8

Of note, two invasive species were recorded, the American Bullfrog (*Lithobates catesbeianus*) and the Red-eared Slider (*Trachemys scripta elegans*). Both species have been known to predate upon Northern Leopard Frogs at various life stages. See Appendix F for raw data.

Boreal Chorus Frog at Coot Lake Frog by A. DuBois

Plains Garter Snake by A. DuBois

Table 2. Species identified on City of Boulder Parks and Rec by site during the 2017 survey period.

Species	Admiral Arleigh A. Burke Park	Area III	E. Boulder Comm. Ctr.	Coot Lake	Dry Creek	Eaton Park	Harlow Platts Comm. Park	Little Dry Creek	Maxwell Lake	Pleasant View Fields
Barred Tiger Salamander	0	23	0	0	0	0	0	0	0	0
Woodhouse's Toad	0	15	3	16	4	0	0	3	0	0
Common Snapping Turtle	0	0	0	1	0	0	0	0	0	0
Painted Turtle	0	1	0	0	0	0	0	0	0	0
Prairie Rattlesnake								3		
Am. Bullfrog (Invasive)	0	0	0	24	0	0	1	0	0	0
N. Leopard Frog (SGCN)	0	0	0	0	0	0	0	0	0	0
Bullsnake	0	1	0	0	0	0	0	0	0	0
Boreal Chorus Frog	0	41	26	8	3	0	0	3	0	0
Plains Gartersnake	0	1	0	2	0	0	0	0	0	0
Red-eared Slider (Invasive)	0	0	0	0	0	0	0	0	2	0
Red-sided Gartersnake (SGCN)	0	0	0	7	0	0	0	0	0	0
	0	**82**	**29**	**58**	**7**	**0**	**1**	**9**	**2**	**0**
									Total	**188**

Plains Garter at Area III by H. Urbanek

Eleven species of reptiles and amphibians were recorded, including the invasive American Bullfrog, but we did not detect Northern Leopard Frogs.

Painted Turtle at Area III

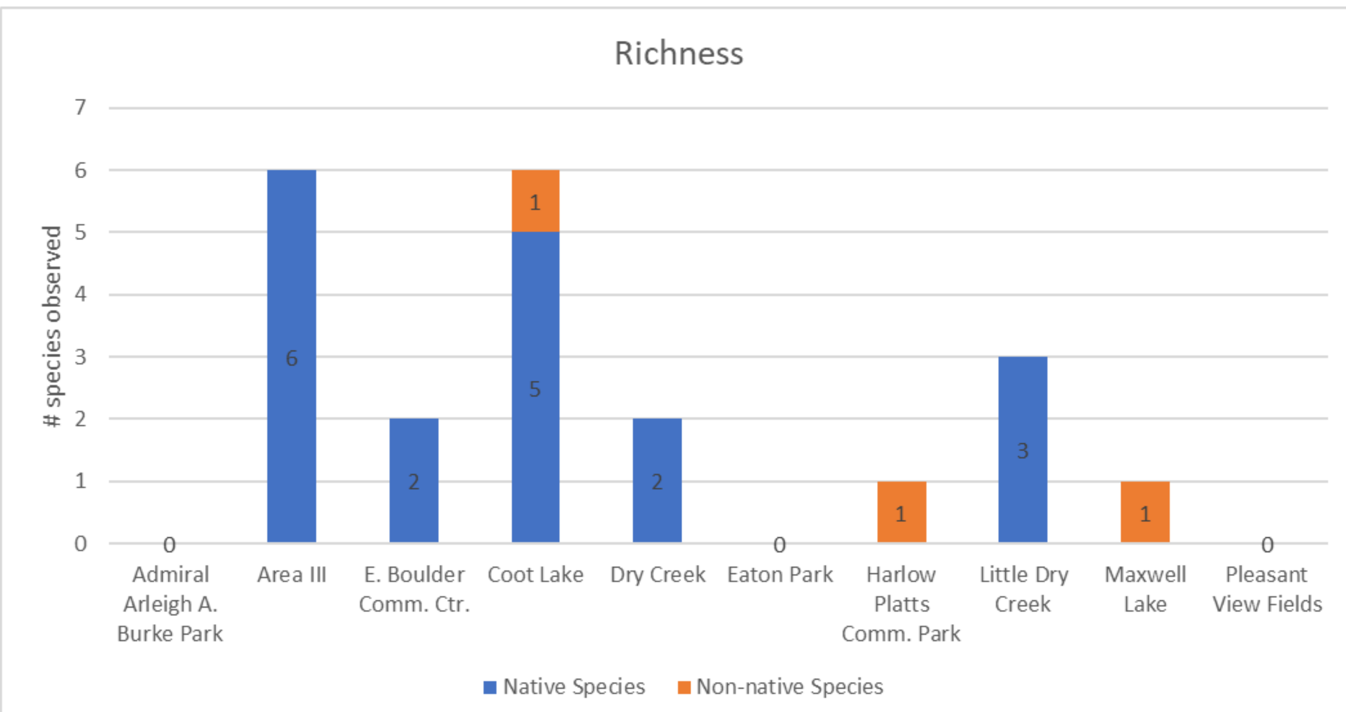
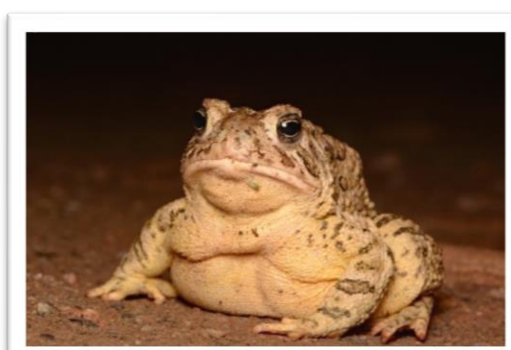


Figure 1. Richness by location: Area III has the highest herptile species richness.



Woodhouse's' Toad found on the road at Coot Lake

Discussion

Northern Leopard Frogs

Like most other amphibians with complex life cycles, Northern Leopard Frog population sizes can fluctuate wildly over time due to variation in larval recruitment, terrestrial predation, parasitism, disease, and stochastic events such as droughts or severe winters (Semlitsch et al. 1996). As a result of this fluctuation, it has been suggested that Northern Leopard Frog populations likely function as metapopulations or patchy populations with frequent extinctions and recolonization events (Boone 2013; Hammerson 1999).

Female Northern Leopard Frogs begin depositing an average of 3,000 eggs a few days after calling begins (Hammerson 1999). In the plains region of Boulder County, most females deposit their eggs by mid-April but sometimes by the end of March if warm weather arrives early (Hammerson 1999). In Colorado, Northern Leopard Frogs attach their eggs to vegetation just below the surface of relatively warm shallows that are usually 3-10 inches (7-15 cm) deep (Hammerson 1999). In the plains region of Boulder County, Colorado, Northern Leopard Frog eggs hatch in 4-15 days (Livo 1981) and larvae of this species spend 2-3 months growing to sizes ≤84 mm before metamorphosis (Boone 2013). Hammerson (1999) found numerous newly metamorphosed Northern Leopard Frogs in late June and early July in eastern Boulder County, Colorado.

Difficulty in Detection

Although no Northern Leopard Frogs were found during the project, we employed multiple survey techniques targeting different life stages through the season and are confident that our survey would have identified them if they were occupying the sites in 2017.

In general, however, Northern Leopard frogs can be difficult to detect due to their activity time during the day and seasonally. While auditory surveys have been used to detect Northern Leopard Frogs (e.g., Trenham et al. 2003; De Solla et al. 2006), in Colorado this species may call at unpredictable hours of the day or night (Tony Auciello, pers. comm.; Andrew DuBois, pers. obs.).

An added difficulty in detecting Northern Leopard Frogs by advertisement call is that the breeding season at individual sites may be short (1-3 weeks) depending on weather conditions (Boone 2013). At low elevations in eastern Boulder County Colorado, male Northern Leopard Frogs begin calling on warm, sunny days in March or April, and usually stop in April, though they may not stop calling until May or early June (Hammerson 1999).

While auditory surveys can be used to gather information about multiple amphibian species, it is often beneficial to use additional detection methods more specific to particular species of interest because not all species are equally detectable (Scott and Woodward 1994) and auditory surveys do not detect younger life stages. In the spring and summer, visual encounter surveys can be used to detect Northern Leopard Frog eggs and in summer and fall the same technique can detect metamorphosed individuals (Graeter et al. 2013). In the spring, summer, and fall, dip-netting and road surveys may detect larval and adult Northern Leopard, respectively (Graeter et al. 2013)

However, we still believe it is possible to detect Northern Leopard frogs in the Boulder County in the future. Research has shown that there is a natural, frequent turnover of Northern Leopard Frogs at ponds (Trenham et al. 2003). Some years few Northern Leopard Frogs are detected followed by years of high intensity calls (De Solla et al. 2006). Therefore, frog populations fluctuate at specific pond sites over time.

Although no Northern Leopard Frogs were found during the 2017 breeding season, there is still reason to believe that Northern Leopard Frogs may occupy the sites in future years.

Presence of Invasive Species

During the project survey two predatory invasive species were located at 3 sites. These sites were Coot Lake, Harlow Platts Community Park and Maxwell Lake (Table 2). The two species were American Bullfrogs and Red-eared Sliders. Both these species have the potential to negatively impact Northern Leopard Frog and other native herptile recruitment and overall population.

American Bullfrogs

American Bullfrogs are one of the most ecologically destructive of invasive alien vertebrate species (Kraus, 2009 & CABI, 2011).

American Bullfrog

In some lowland areas of Colorado (Hammerson 1999) and elsewhere (Lannoo et al. 1994), Northern Leopard Frog population reductions or extirpations have been associated with the presence of the increasingly abundant American Bullfrog (Hammerson 1982; Johnson et al. 2011), with both larval and adult life stages negatively impacting Northern Leopard Frogs (Hammerson 1999).

There are numerous reports of the American Bullfrog preying on the Northern Leopard Frogs (Boone 2013; Leonard, Brown & Storm, 1993 & McAlpine & Dilworth, 1989). They have also been documented to eat small fish, young ducklings, sparrows, snakes, wood ducks, and amphibians (Stewart, 1967, Hewitt, 1950, McAtee, 1921 & Wright, 1920).

Hammerson (1999) suggests that eggs and the smallest of Northern Leopard Frog larvae may be vulnerable to predation by American Bullfrog larvae (Ehrlich 1979). American Bullfrogs have reduced the palatability for NLF tadpoles, but Northern Leopard Frogs appear readily palatable to predators such as salamanders, turtles, and fish (Walters 1975; Woodward 1983).

In some areas in Colorado, human alterations to wetlands that have increased water depth and permanence has led to the replacement of Northern Leopard Frogs by American Bullfrogs and fishes, particularly near large rivers and other permanent water bodies (Hammerson 1999). American Bullfrogs are extremely capable of colonizing new habitats and travel up to five miles between suitable water bodies (Jones et al., 2016). Whereas the known migratory range of the Northern Leopard Frog has been reported as 0.3 – 1.9 miles (Smith and Keinath 2007). See Appendix B and C for supplemental management information on bullfrog removal.

We recommend the removal/continued exclusion of American bullfrogs from all target NLF sites (Area III, East Boulder Community center, Coot Lake and Harlow Platts) to increase the habitat suitability for Northern Leopard Frogs.

Red-eared Sliders

Native to eastern and central North America, Red-eared Sliders have been introduced to aquatic habitats in the west, including Colorado, where they compete with, eat, and spread diseases to native herpetofauna (Jones et al. 2016). Like the American Bullfrog, they have been documented to eat frog eggs and frog tadpoles (Cahn 1973; Minyard 1947). In addition, Pritchard and Trebbau (1984) found that *T. scripta callirostris* in Venezuela captures waterfowl by grabbing their legs and dragging them underwater to drown. If it is feasible to eliminate Red-eared Sliders from a property, consider methods of removal (O'Keeffe 2009).

Red-eared Slider plastron

IF IT IS FEASIBLE TO ELIMINATE RED-EARED SLIDERS FROM A PROPERTY, CONSIDER METHODS OF REMOVAL

Permits and Regulations: There is no bag limit on American Bullfrogs for private or commercial purposes in Colorado under a Colorado fishing license (CPW 2017). Red-eared Sliders are considered Unregulated Wildlife under regulation (#1103(B)) and are exempted from the requirements of Colorado Parks and Wildlife Commission regulations (CPW 2016a).

Presence of Predatory Fish

Green sunfish at Coot Lake

The presence of fish may critically impact populations of Northern Leopard Frogs (Boone 2013). The presence of fish may exclude many amphibian species from ponds, with the highest diversity of amphibians existing in temporary pools devoid of fish (Boone 2013). All fish are predatory towards amphibians and may have an overall negative impact on amphibian species richness (Werner et al. 2007) and may exclude Northern Leopard Frogs from ponds (Rorabaugh 2005). Both adult and larval life stages of Northern Leopard Frogs are vulnerable to predation by various game fishes (Bagdonas 1968).

Emery et al. (1972) found adult Northern Leopard Frogs overwintering in ponds with trout, which are known predators of adult frogs. Frogs were found to be a small component of the trout's summer diet, but made up 20% of the winter diet, demonstrating that predation in aquatic environments may affect larvae as well as adults (Emery et al. 1972).

While no trout was documented during this study, all fish are a threat to Northern Leopard Frogs. We found numerous Carp at North Shore and other predatory fish, such as Green Sunfish and Large-mouthed Bass, at Maxwell Park and Coot Lake. *All fish are considered predatory and threaten amphibians. See here for a list of fish in Colorado:
http://cpw.state.co.us/learn/Pages/Aquatic.aspx

Porej and Hetherington (2005) found Northern Leopard Frog tadpoles were most abundant in permanent ponds with shallow areas, regardless of the presence of fish, and these shallow areas appear to allow amphibians refuge from predation (Porej and Heatherington 2005).

Permits and Regulations: Fish are game species falling under the direct purview of Colorado Parks & Wildlife and collecting more than the bag limit (5) (CPW 2017) may require a scientific collection permit (CPW 2016b).

Management: In newly constructed wetlands, it is important to create areas of refuge by either excluding fish altogether or provide shallow habitat for amphibians where they can escape fish. Non-native fish can be removed completely.

We recommend that sites for NLF recovery employ management techniques to exclude fish from NLF breeding areas and remove non-native fish from wetlands.

Roads

Roads may represent important barriers to Northern Leopard Frog movements, with road crossing putting this species as well as other amphibians at an apparently high risk of mortality (Boone 2013).
In an investigation of the effects of traffic density on amphibians crossing a 20 km stretch of road in a Canadian park, more than 54% of the amphibians recorded were dead on the road (Mazerolle 2004). In the same study, *Northern Leopard Frogs appear even more susceptible with an average of 88% of the observed frogs found dead on the road* (Mazerolle 2004).

Some attempts have been made to study road crossing corridors for amphibians to move to and from their breeding grounds near highways, though this research area/management practice is relatively unexplored and unapplied (Boone 2013). Northern Leopard Frogs have been found to use relatively short underground corridors with relatively large openings (>0.5 m) and some light permeability at the top to cross roads (Wolz et al. 2008).

In 3.5 hours of road cruising, we identified 12 Woodhouse's toads on the road at Coot Lake, East Boulder Community Center and Dry Creek. It is likely that most reptiles and amphibians found on City of Boulder lands are threatened by roads.

It is unclear the impact of roads on wildlife at City of Boulder Parks and further research is still needed. While road crossing structures at specific sites may be important in the future, we recommend the City of Boulder first work to improve native populations throughout the target locations.

Vegetative Community/Succession

Maintaining diverse local landscapes reflecting historic habitat diversity and restoring or artificially simulating natural processes (e.g. creation of beaver dams) to maintain Northern Leopard Frog populations (Boone 2013) is important.

Northern Leopard Frogs are negatively associated with forest habitat (Guerry and Hunter 2002; Houlahan and Findlay 2003; Werner et al. 2007) and Boone (2013) has suggested they may be vulnerable to the processes of succession. Cleared areas may convert back to forest, leading to shifts in amphibian species composition and possible population extinction of species associated with open canopies where nearby suitable habitat is unavailable (Boone 2013).

Northern Leopard Frogs will breed in permanent or temporary waters (Hammerson 1999), and open-canopy ponds have been demonstrated to produce the greatest growth and survival of Northern Leopard Frog tadpoles (Werner and Glennemeier 1999; Werner, Skelly, Relyea, and Yurewicz 2007), possibly due to greater food resources as food supplementation increased the growth and survival of tadpoles in closed-canopy ponds (Werner and Glennemeier 1999).

Northern Leopard Frogs prefer ponds that have emergent or submerged vegetation, which may help with oviposition and cover from predators (Jennings and Hayes, 1994b). For example, Northern Leopard Frogs in the Pacific Northwest do not breed in water bodies without vegetation (Nussbaum et al., 1983).

Preferred habitat for Northern Leopard Frog: Breeding sites: permanent or temporary waters (Hammerson 1999), open-canopy ponds (Werner and Glennemeier 1999, non-acidic water, water depth of 10–65 cm in full sun, on the north side of ponds, and with emergent, non- broad-leaved vegetation (Pope et al. 2000).

Cattails: Several sites we visited were inundated with cattails. While cattails are a native and necessary vegetative structure for Northern Leopard Frogs, they can also grow into large thick monocultures. Currently at East Boulder Community Center, cattails are controlled routinely.

We recommend maintaining cattails in potential Northern Leopard Frog breeding sites, but ensuring that some of the water remains open. Cattails should continue to be controlled at East Boulder Community Center as well as any other sites with encroaching cattails. See Appendix E for more details on specific methods.

Cattails at East Boulder Community Center

Contaminants

According to the global amphibian assessment, contaminants are the second most important threat to global amphibian populations (Stuart et al. 2004). Rohr et al. (2008) found that atrazine suppressed Northern Leopard Frog immune systems and those frogs exposed to atrazine were infected to a greater degree than those unexposed to the herbicide. Gendron et al. (2003) also showed pesticide exposure resulted in greater parasite infections in Northern Leopard Frogs.

Contaminants have also been suspected or associated with deformities in the Northern Leopard Frog (Harris et al. 2001; Taylor et al. 2005; Skelly et al. 2007). As with other amphibians, Northern Leopard Frogs appear to be sensitive to endocrine disruptors such as the estrogen mimic and herbicide, atrazine (Hayes et al. 2002). Roundup, the most commonly used herbicide in the US, is lethal to Northern Leopard Frogs (Relyea 2005) and causes morphological changes in their tadpoles (Relyea 2012).

Managers should exercise good judgement when applying herbicides, pesticides, or fertilizers near area where Northern Leopard Frogs were observed and be mindful of label instructions when applying herbicides as a management tool around water bodies.

Priority Sites

Management Recommendations

Based on our survey results and current existing conditions, Area III, Coot Lake, East Boulder Community Center and Harlow Platts are our top sites for Northern Leopard frog management (Table 3). These sites have the highest species richness, abundance, and potential or currently suitable habitat for Northern Leopard Frogs.

Targeted management actions identified in Table 4 will yield the most success to NLF recovery at these top four sites in Boulder.

Management actions include American bullfrog removal, volunteer monitoring, habitat alterations and re-colonization and re-introductions (Table 4). Specific management for these sites will vary by resources available and timing. We highly encourage increased and regular communication between City of Boulder agencies with similar conservation and management objectives to continue this effort.

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Through a combination of communication, education, invasive species and habitat management and monitoring, we believe Northern Leopard Frogs have the potential to recolonize these areas in the City of Boulder.

Northern Leopard Frog by A. DuBois

Table 3. Priority Sites for Northern Leopard Frogs and suggested management

Site	Values	Target Management
Area III	Highest species diversity site	1. Prevent A. Bullfrog dispersal to site 2. Create additional ephemeral ponds with varying depths and vegetation structure 3. Volunteer Monitoring
Coot Lake	Wetland system is potentially favorable for NLF *(pit-trapped adult NLF in 2004, high amphibian and reptile species richness with inclusion of 2015-2016 Spiny Softshell observations)*	1. Remove/ control A. Bullfrogs from immediate vicinity 2. Remove A. Bullfrogs from Boulder Reservoir 3. Remove non-native predatory sportfish (i.e. Large-mouthed Bass) from wetland system and exclude native fish, where NLF are likely to breed 4. Volunteer Monitoring
East Boulder Community Center	2014 record of NLF eggs; Potential for recolonization	1. Remove A. Bullfrogs from adjacent water bodies 2. Continue with vegetation management (i.e. cattail knock-down/ control) 3. Volunteer Monitoring 4. Potential: Northern Leopard Frog Reintroduction (Post A. Bullfrog removal)
Harlow Platts	Potential for NLF re-colonization	1. Remove A. Bullfrogs 2. Volunteer Monitoring

Table 4. Descriptions of General Management Recommendations

Management Type	Descriptions
American Bullfrog Removal	By removing this invasive species, rapid recolonization may occur if NLFs still occur in the vicinity. This practice is possible as demonstrated by Orchard et. al. in British Columbia (2011) See Appendix B & C. There is no bag limit on American Bullfrogs for private or commercial purposes in Colorado under a Colorado fishing license (CPW 2017).
Volunteer Monitoring	Monitoring is vital to management and restoration by measuring success. Volunteer Monitoring Programs repeatedly demonstrate success across the U.S. of species presence/ absence surveys. Such a program would help direct staff to more in-depth surveys and management actions. One established program is AZA's FrogWatchUSA (Appendix D).
Habitat Alterations	The establishment of healthy NLF habitat will provide many other priority species (e.g. birds and reptiles) improved systems from which all will thrive. Working closely with a landscape architect, such as Great Ecology (a Denver company), would provide specific prescriptions and actions towards this restoration process. Providing for natural ecosystem function will cost less than likely expensive routine management actions (Appendix E.
Re-colonization and Reintroductions	Providing opportunities for natural recolonizations of native species are important for ecosystem functions and budgets. In ecosystems, eliminating threats significantly increases likelihood of sustained re-colonization opportunities. Furthermore, reintroductions are a possibility at sites where natural re-colonization is unlikely.

Take it to the Ribbit

Northern Leopard Frog

ADAPTATION
ENVIRONMENTAL SERVICES

Adaptation Environmental Services
adaptationenvironmental.com

info@adaptationenvironmental.com

PO Box 6030

Denver CO 80206
(720) 722-3AES

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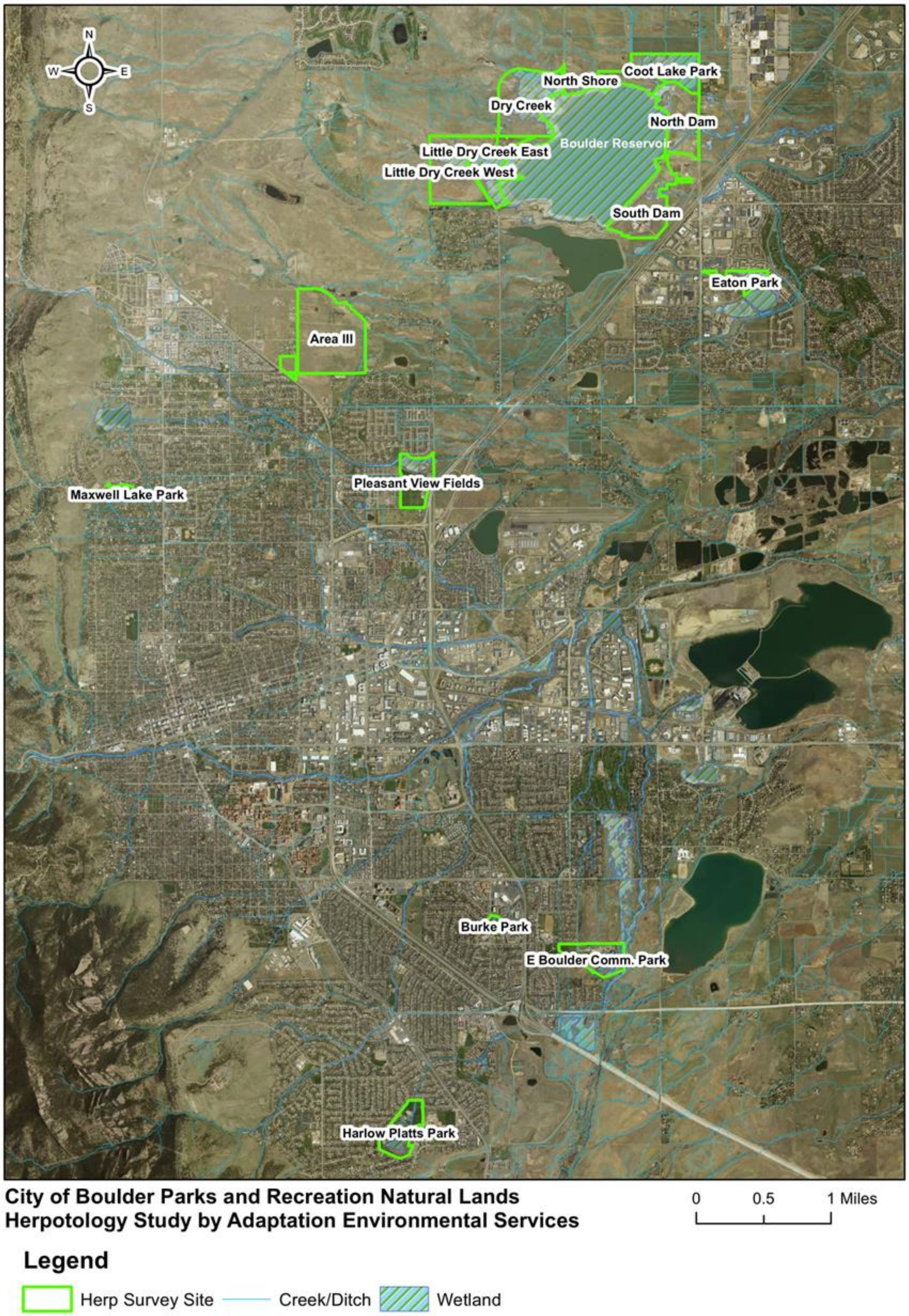
List of Appendices

Appendix A: City of Boulder Herpetological Study Site Map



Appendix B: Bullfrog Management Hot-Sheet

American bullfrogs

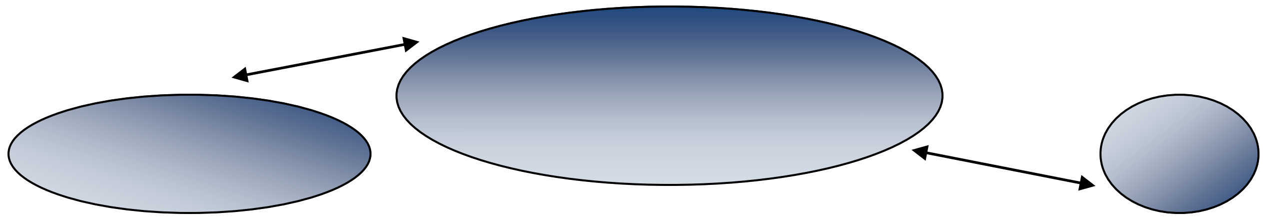
Species to Recover

- Northern Leopard Frog
- Common Garter Snake
- *...and others*

And here's how...

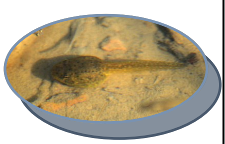
"Go for eradication, not management"

- Tom Jones (AZ G&F)



1. Determine metapopulation for eradication and dispersal routes (e.g stock tanks, ponds, rivers, and reservoirs)
2. Identify methods and funding sources for 3-5 years
3. START systematic eradication

Tools



Hand-capture	Dip-net/ Seine	Gig
Hawaiian sling (i.e. underwater spear)	Pellet gun or .22 cal hollow-point	Electro-frogger and fishing system

Important Resources

Akins C.M. and Jones T.R. 2013. Invasive Bullfrog Removal in the American Southwest. *Presentation* to ASIH/ SSAR.

Jones L.C. *et al.* 2016. Partners in Amphibian and Reptile Conservation, Technical Publication HMG-5, Birmingham. 193 p.

Orchard S.A. 2011. Pages 217-221 In: Veitch, C. R.; Clout, M. N. and Towns, D. R. (eds.). 2011. Island invasives: eradication and management. IUCN, Gland, Switzerland.

More information:

info@adaptationenvironmental.com or ***(720) 722-3237***

ADAPTATION
ENVIRONMENTAL SERVICES

Appendix C: Bullfrog Management Paper

Orchard S. A., 2011. Removal of the American bullfrog, Rana (Lithobates) catesbeiana, from a pond and a lake on Vancouver Island, British Columbia, Canada. In: Veitch CR, Clout MN, Towns DR (Eds) Island invasives: eradication and management. IUCN (Gland, Switzerland): 1–542.

Removal of the American bullfrog *Rana (Lithobates) catesbeiana* from a pond and a lake on Vancouver Island, British Columbia, Canada

S. A. Orchard

BullfrogControl.com Inc., 69A Burnside Road West, Victoria British Columbia, Canada, V9A 1B6. <bullfrogcontrol@shaw.ca>.

Abstract The American bullfrog is listed as one of the 100 Worst Alien Invasive Species internationally because it is adaptable, prolific, competitively exclusive, loud, and predatory. An expectation of profits from the sale of frog legs for human consumption has led to bullfrogs becoming established on most continents as well as on islands in western Canada and the western United States, Hawaii, throughout the Caribbean, Crete, Indonesia, Japan, Singapore, Sri Lanka, and Taiwan. The ecological impact of bullfrogs on islands can be profound especially where ecologically vital freshwater resources may be limited. While the problems created by bullfrogs are well-documented, there have been few technological advances in their effective control and management. In 2006, a programme was initiated to design, field test, and refine new equipment and tactics to capture individual bullfrogs at rates to exceed replacement. The programme also hoped to demonstrate that bullfrog eradication is a feasible and practical option. The principal manual capture technique is modified fisheries electro-shocking tailored specifically for capturing juvenile (<80 mm body length) and adult (>80 mm body length) bullfrogs. Bullfrog tadpoles are not hunted directly but collected as they reach the latter stages of metamorphosis or have recently transformed. Clear patterns have emerged from comparative data sets collected between 2007 and 2009 that identify some basic units of bullfrog eradication, including logistical and time sequence requirements for successful removal of all age-classes from a single lake or pond after only one successful spawning. The two case studies presented here illustrate patterns useful for interpreting catch results and for predicting the time, effort, and costs in carrying out complete site eradications. In both examples, 'site eradication', i.e. reducing numbers of all bullfrog age-classes at one site from hundreds or thousands to zero, was carried out by one two-person team and achieved over three years with only a few nights effort per site per year. The cost of running this programme is currently $400/night/2-person team. At Amy's Pond (0.4 km perimeter distance), 1587 adult and juvenile bullfrogs were collected after 23 nights of effort spread over 3 years for a total cost of CAN$9200. At Glen Lake (2 km perimeter distance), 1774 bullfrogs were collected after 41 nights of effort spread over 3 years for a total cost of CAN$16,000.

Keywords: Amphibian management, eradication, control, site eradication, electro-frogging, cost-effective

INTRODUCTION

Populations of alien invasive American bullfrogs, (*Rana (Lithobates) catesbeiana),* are now established in western North America, western Europe, south and east Asia, and Central and South America. Historically, live bullfrogs were exported from their native range in eastern North America to establish new wild populations supplying international markets for frog meat. Bullfrogs acclimatise readily to habitats ranging from temperate to tropical. Rapid population growth rates coupled with migration outward from source population leads eventually to bullfrogs in all habitable lakes and ponds. The result is potentially catastrophic for native species that are prey to this large, abundant and aggressive non-native predator. Eradication of bullfrog populations has been proposed out of concern for the sustainability of native ecosystems and species diversity, but also because of human objections to the noise produced by choruses of large male bullfrogs and their consequent effects on property values. Continental bullfrog populations can spread out geographically over wide areas. However, island populations are area-constrained, often with relatively few vital freshwater spawning 'sites' available and surrounding habitat that is bounded on all sides by a barrier of saltwater. Islands therefore have advantages if bullfrog eradication is to be attempted. Once eradication is achieved, islands should also be easier to keep bullfrog-free.

Vancouver Island is the largest island on the west coast of North America (32,134 km^2). Its cool mountainous interior, vast tracts of rocky terrain and thick forest restrict or inhibit bullfrog dispersal. However, bullfrogs have been released and are spreading from multiple disjunct pocket populations along the low, warm, coastal zone of south-eastern Vancouver Island. They have also been introduced to smaller, adjacent islands, and have for many decades populated regional Vancouver on the adjacent mainland coast (Fig. 1).

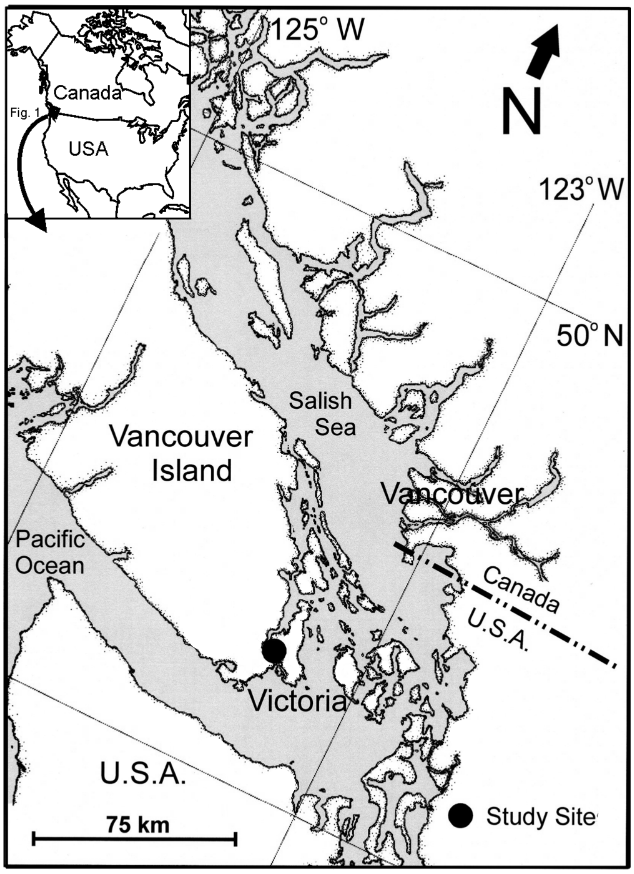


Fig. 1 Location of case study sites on the Saanich Peninsula, Vancouver Island, British Columbia, Canada.

Pages 217-221 In: Veitch, C. R.; Clout, M. N. and Towns, D. R. (eds.). 2011. Island invasives: eradication and management. IUCN, Gland, Switzerland.

There are few published case studies of bullfrog eradication, and the few successful examples were laborious and costly (Adams and Pearl 2007; Kraus 2009). In England in 1996, the eradication of bullfrogs from only a few small ponds cost approximately US$70,000, including the earth-moving equipment that ultimately destroyed freshwater habitat (Banks *et al* 2000; CABI Bioscience 2005). In Germany between 2001 and 2004, bullfrogs were eradicated from five ponds with help from a volunteer force of 20 as well as the local fire department and an 'electro-fish' team. Cost estimates for this project were US$80,230/pond/year for five ponds or US$409,000 annually (Reinhardt *et al* 2003; Nehring and Klingenstein 2008). These European case studies utilised large work forces and heavy equipment beyond the budgets of many agencies. Other attempts at managing or eradicating invasive bullfrog populations have used netting, barrier fencing, seining, shooting, gigging (spearing), pitfall traps, and pond draining. These technologically unsophisticated attempts have been mostly ineffectual, excessively labour-intensive, and unable to keep pace with the bullfrogs' prolific reproduction and mobility. Such attempts are particularly difficult where populations have grown to maturity and have dispersed geographically before any control efforts were attempted. A general impression is then formed that bullfrog eradication may be feasible through the intense countervailing efforts of a large and dedicated workforce, but the time-consuming exertions required also make these measures exorbitantly expensive and generally impractical (Adams and Pearl 2007; Krause 2009).

In this paper I describe cost-effectiveness of methods used to remove bullfrogs from a pond and a lake on Vancouver Island, British Columbia, Canada. For the purposes of this study, I use the following definitions:

A 'bullfrog site' is a discrete body of standing water – generally a lake, pond, or pool – where some or all life stages of bullfrogs are present. When all sites are identified regionally and brought 'under control' by the eradication programme then eradication is inevitable because standing water is vital for population sustainability and growth.

'Productive sites' have the essential elements of: 1) permanent water that does not freeze to the bottom of become anoxic in winter; and 2) summer surface temperatures that reach and exceed 25° C. for an interval of weeks in mid- to late summer to facilitate reproduction. Permanent water is a requirement because, at this latitude, bullfrog tadpoles will commonly take 24 to 36 months to reach metamorphosis.

'Non-productive sites' are either: 1) impermanent pools that trap and kill bullfrog tadpoles before they metamorphose; or 2) too cool in summer for reproduction to occur, e.g., <25° C. Non-productive sites are useful only to migrating bullfrogs as way stations or as over-wintering sites.

STUDY SITES

The two case studies presented here are drawn from preliminary results of a long-term regional control program that encompasses a cluster of lakes and ponds at the isthmus of the Saanich Peninsula, at the extreme southern end of Vancouver Island, including the City of Victoria (Fig. 2). The particular significance of the case studies presented is that the sites are dissimilar in size and habitat characteristics, but comparable in their stage of bullfrog colonization. In both instances, fieldwork began shortly after the arrival of adult bullfrogs and after one spawning had occurred at each site. It was unknown at the start how many tadpoles would reach metamorphosis and how much time and effort would be required to capture them all post-transformation. The innovative manual capture technique developed specifically for this program was, at that stage, untested. At the end of the third field season (2007 – 2009) it was possible to quantify material costs, time and effort required to de-populate both sites using the 'electro-frogger' technique.

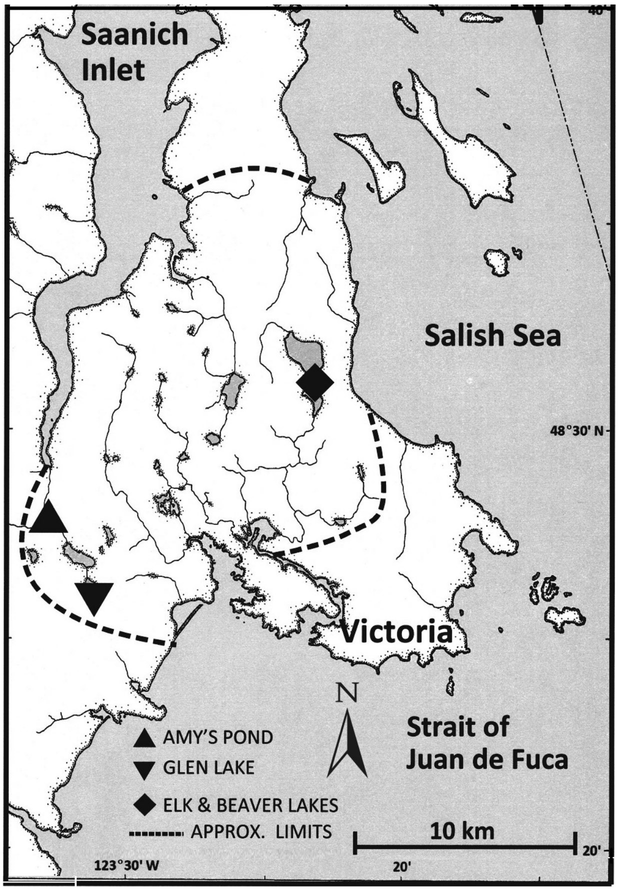


Fig. 2 Site of the founding bullfrog population (diamond) and current approximate distribution limits of bullfrogs on the Saanich Peninsula, British Columbia, including the case study sites Amy's Pond and Glen Lake.

1. Amy's Pond

At Amy's Pond the margins were essentially bare of aquatic and emergent vegetation throughout the summer. This meant that despite somewhat turbid water, there was good visibility at the surface and accessibility to the margins. With a perimeter distance of only 0.4 km, many circuits of Amy's Pond could be made in a single three-hour evening session and virtually every individual of every post-larval age-class present could be located and captured on any given night.

2. Glen Lake

Glen Lake had a perimeter distance of about 2 km, or five times the margin of Amy's Pond. It was also much more florally complex with many species of aquatic, floating, and emergent plants, as well as riparian shrub and tree thickets. These all provided effective cover for bullfrogs, impeded vision during searches, and interfered with the ability to manoeuvre during approach and capture. Unlike at Amy's Pond, only one thorough circuit of Glen Lake could be completed per evening and this only when bullfrog numbers were very low. While bullfrog densities were high, only a portion of the lake margin could be cleared per evening session.

MATERIALS AND METHODS

For this programme, one two-person team is the minimum manpower unit so what follows are the requirements to equip, transport, and fund one team. Transportation includes a utility vehicle and a very sturdy inflatable rowboat. Essential field equipment includes a modified fisheries electro-shocker, 'electro-frogger' pole, powerful spotlights, and two chest freezers, with one modified to maintain a temperature slightly above freezing. The freezers were used in a two step euthanasia procedure.

On southern Vancouver Island, the field season began in April and ended around the beginning of October. Fieldwork was weather-dependent and incompatible with excessive wind (> 15 km/hr) or rain. As explained, the case studies are part of a larger regional programme that encompassed many more sites. Regionally, we worked every night with suitable weather, which amounted to 93 nights in 2007 (19 sites/4,479 bullfrogs), 114 nights in 2008 (20 sites/3,430 bullfrogs), and 125 nights in 2009 (28 sites/3872 bullfrogs). Costs averaged about $400/night/team or CAN$37,200 in 2007, CAN$45,600 in 2008, and CAN$50,000 in 2009. The programme also included daytime site assessments, examination and measurement of the catch, dissections, data compilation and analysis, and write-up of results. On-going annual maintenance costs included permits and licences, liability insurance, and automobile insurance, as well as routine costs such as fuel, facilities, utilities, website, public relations and equipment repair and replacement.

In 2006, a prototype electrode-fitted pole (electro-frogger) was developed and field tested, and more refined, patent-pending versions have been employed since 2007. During the summers of 2007 to 2009, a two-person team applied this manual capture technique for four-hour sessions on every evening that weather permitted. A four-hour session included loading and unloading equipment, so the time locating and capturing bullfrogs was approximately three hours. Teams worked at night from an inflatable boat, with one person to manoeuvre and position the boat while the second person located and caught juveniles (< 80 mm body length) and adults (> 80 mm) frogs. Pond and lake margins were scanned by spotlight to detect bullfrogs by their eye reflections. Vocalisations from adult male bullfrogs also independently identified their whereabouts. Bullfrogs were dazzled and transfixed by the spotlight's beam as we approached. Then the electrode-fitted pole was used to generate a subsurface concentrated electrical field of < 50 cm diameter near the target bullfrog. The electrical field stunned and temporarily paralysed juvenile and adult bullfrogs for 30 seconds to one minute, which was enough time to get them into a container. The technique is humane, species-specific and only targets one bullfrog or small groups of bullfrogs in very close proximity to one another. Capture rates, on any given night, are influenced by each site's habitat characteristics, weather, and bullfrog density and demographics.

For euthanasia, bullfrogs were placed into a chest freezer modified to lower their core body temperature to just below 2° C. After at least 12 hours they are transferred to a conventional deepfreeze that quick-freezes the now cold-stupified bullfrogs. They remain in the second freezer for at least 48 hours. Cold is a natural anaesthetic for amphibians and freezing leaves an uncontaminated, chemical-free carcass that can be safely used to feed injured wildlife, donated to high schools for educational dissections, or composted.

RESULTS

In the spring of 2007, Amy's Pond and Glen Lake were at the same initial stages of bullfrog colonisation. At Amy's Pond, few adults were present, there were a few new arrivals, and there had been one successful spawning 12 to 24 months previously, which produced many tadpoles. Around mid-summer 2007, this single cohort of bullfrog tadpoles began to metamorphose and on 30 August we collected 237 transforming or recently transformed juveniles and five adults. Transformations continued throughout the remainder of the summer, but the number of juveniles captured per evening declined markedly with each subsequent visit in 2007 (Fig. 3a).

Fieldwork re-commenced in April 2008 (Fig. 3b) as the over-wintered remnant of the same cohort became active and began to complete their transformations. By the end of the 2008 season, we could find no bullfrogs of any age-class.

Our 2009 results confirmed that the metamorphosis event that began mid-summer 2007 was essentially over by mid-summer 2008. Spawning was prevented from 2007 onward by clearing the pond of all adults prior to the mid- to late-summer spawning period. By 2009, Amy's Pond was tadpole-free, though there was a small but persistent influx of juveniles and young adults from adjacent lakes and ponds.

Ultimately, we removed 1587 bullfrogs from Amy's Pond by investing 3 hours of collecting effort in each of 23 nights spread over 3 consecutive summers. By the end of the 2008 season, bullfrog numbers had been reduced to zero and all bullfrogs encountered thereafter were the result of immigration or release. The total cost for this three-year (23 nights) effort was CAN$9200 (Table 1).

Like Amy's Pond, Glen Lake was in the earliest stage of bullfrog colonisation in 2007 with just one successful spawning. By mid-summer 2007, bullfrog tadpoles first noted in late-2006 had begun to metamorphose. On 25 July, we collected 59 bullfrogs (Fig 4a), all but one of which was either in the latter stages of metamorphosis or had just recently completed transformation. From 25 July to 16 August, we concentrated on one end of the lake where the number of juveniles was high and the conditions were especially difficult due to extensive patches of cattail, rushes, water lilies, various floating aquatic plants, and willow thickets. By 17 August, one end of the lake was clear of bullfrogs and efforts were moved to the opposing end, which was also heavily vegetated. Tadpole metamorphosis followed a pattern similar to Amy's Pond, commencing in mid-summer 2007 with transformations continuing throughout that summer (Figs. 3a, 4a).

Table 1 Comparison of site characteristics with time and cost of achieving 'site eradication'

Sites	Perimeter	Littoral/ Riparian	Nights/year	Catch/year	Cost/year	3-year total catch/cost
Amy's Pond	0.4 km	Florally barren	8/2007 10/2008 5/2009	871 661 55	$3200 $4000 $2000	1587/$9200
Glen Lake	2.0 km	Florally abundant & complex	16/2007 16/2008 9/2009	1376 366 32	$6400 $6400 $3600	1774/$16,400

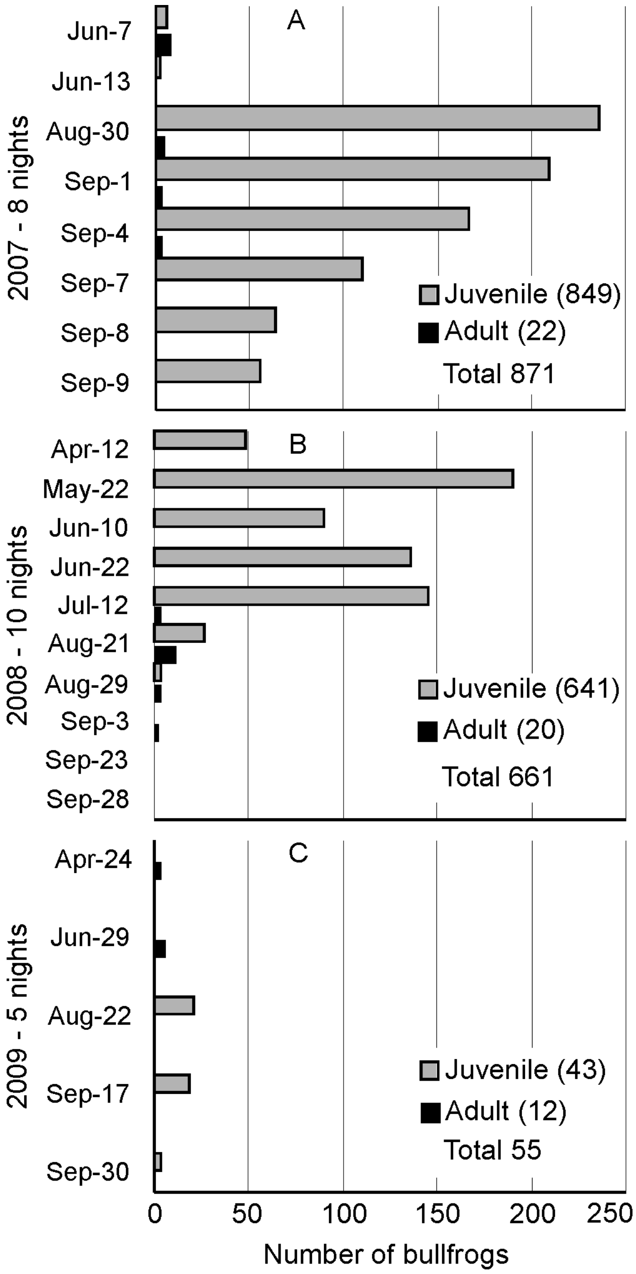


Fig. 3 Amy's Pond chronology and nightly capture results 2007- 2009 (n = 1587).

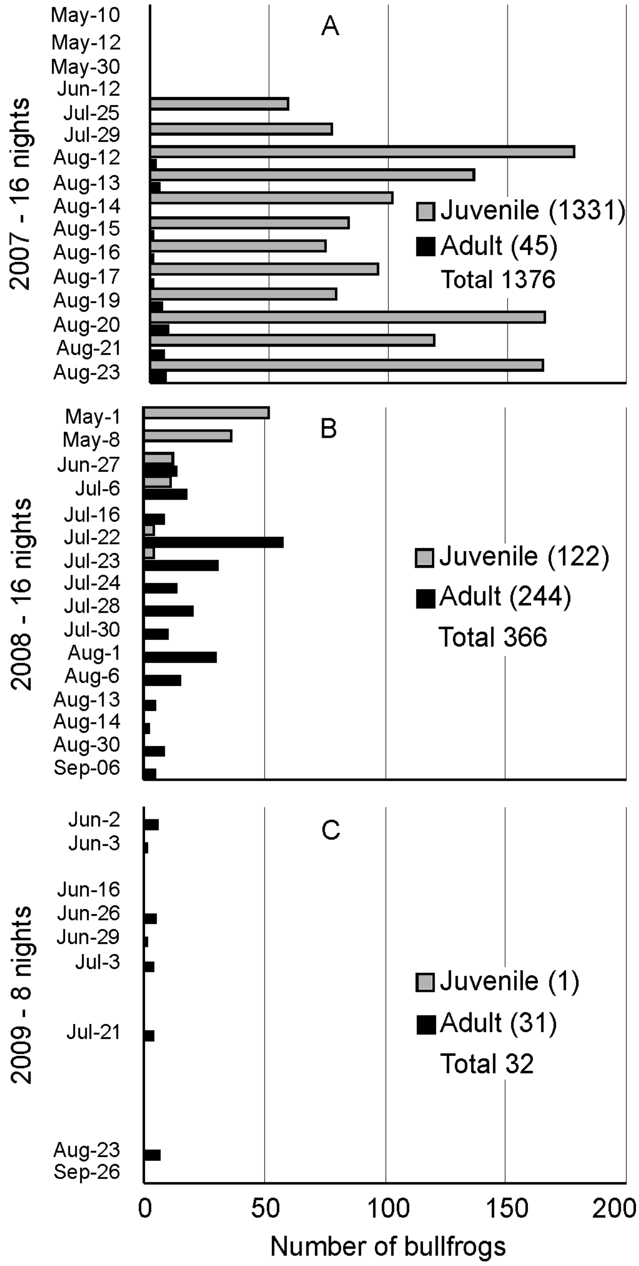


Fig. 4 Glen Lake chronology and nightly capture results 2007 - 2009 (n = 1774).

The 2008 season (Fig. 4b) began with a resumption of metamorphosis that tapered off to near zero by mid-summer. Adults recorded from 27 June onward undoubtedly included a few immigrants but were primarily Glen Lake juveniles whose body lengths had grown rapidly to young adult size (>80 mm body length) before we were able to locate and capture them.

In 2009, there were only a few newly arriving adults and juveniles. Total costs for this three-year (41 nights) effort was CAN$16,400 (Table 1).

DISCUSSION

By the end of the 2009 field season, all age-classes of bullfrogs had been successfully removed from both sites. Excluding repopulation through natural immigration or human translocation, both Amy's Pond and Glen Lake were then free of bullfrogs.

The two case studies are comparable because both had only one spawning per site. Without knowing how many eggs were produced by each of the two adult females there was nevertheless remarkable similarity in the timing and interval of tadpole transformation, and in the numbers of metamorphs/juveniles ultimately captured. If it is assumed that each female produced thousands of eggs, then there must have been considerable mortality in the tadpole stage to have resulted in only about 1,500 metamorphs/juveniles taken from each site. This is one reason to ignore the tadpole stage and concentrate on capturing the post-metamorphic stages if tadpole mortality is consistently high.

Another similarity between these case study results is a pattern of asynchronous cohort transformations from tadpole to juvenile that stretches over 12 months and two calendar years. For example, for each cohort there was an induction stage to this incremental metamorphosis that commenced about mid-summer of one year and continued throughout the remainder of the active season, e.g., July to October. However, some of this tadpole cohort did not metamorphose before the onset of winter, completing transformation the following spring in a protracted conclusion stage, e.g., April to August that peaked in spring. If this pattern proves to be consistent, a manual capture technique that targets only post-metamorphic stages will, by necessity, require two calendar years or more to clear a

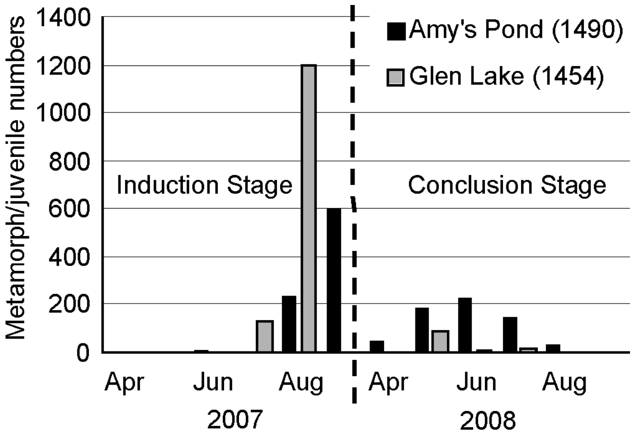


Fig. 5 Comparative capture results of the metamorph/juvenile size-classes (<80 mm body length) from Amy's Pond and Glen Lake. Both sites exhibited a 2-stage incremental cohort metamorphosis.

lake or pond of all bullfrogs. If spawning has occurred in two or more consecutive years then the removal process will take three or more calendar years to complete. At Amy's Pond, 57% (849) of our 2-year total of 1490 metamorphs/juveniles were captured during the induction stage in 2007 and the remaining 43% (641) during the conclusion stage in 2008. In Glen Lake, 92% (1332) of our 2-year total of 1454 metamorphs/juveniles were captured during the induction stage in 2007 and the remaining 8% (122) during the conclusion stage in 2008 (Fig. 5).

The electro-frogger manual capture technique demonstrated a capacity to collect as many as 241 bullfrogs per three-hour session at Amy's Pond and 181 per three-hour session at Glen Lake (Fig. 3, 4).

CONCLUSIONS

1. The manual capture 'electro-frogger' technique, when competently and diligently applied and when coupled with various pieces of essential accessory equipment, successfully located and captured juvenile and adult bullfrogs at rates that far exceeded replacement.

2. The 'electro-frogger' does not place all individuals of the population at risk simultaneously because the tadpole stage is largely unaffected. However, as tadpoles transform from landlocked aquatic larvae to semi-aquatic juveniles they rise to the surface and become vulnerable to capture.

3. At the latitude of Vancouver Island, adult bullfrogs can be successfully located and removed as they emerge from winter torpor (April – May) and prior to the spawning season (July – September). This means that with appropriate intensity of effort, bullfrog reproduction can be prevented within the first few weeks of the first year of an eradication programme and similarly prevented in subsequent years.

4. A singe two-person team can eradication bullfrogs from small to medium-sized water bodies but the number of nights per year required per year will vary depending upon perimeter distance and habitat characteristics at each site as well as the age-class complexity of the bullfrog population. An additional team would not have reduced the number of nights or number of years required to bring Amy's Pond under control. However, the number of nights per year spent on the much larger Glen Lake would have been significantly reduced by adding a second team. The number of years, however, remains independent of the number of teams deployed since each cohort of tadpoles begins to metamorphose in one calendar year and finishes in the next.

5. Where bullfrogs have spawned more than once in the same year, at the same site, the number of resultant juveniles will be numerically greater than reported here. However, they can still be removed within two years from the onset of metamorphosis if sufficient effort is applied in terms of increasing the number of field nights per year and/or increasing the number of teams active per site per night. Where there has been multiple spawning in each of two or more consecutive years, then it will take three to four years to achieve the same result with appropriate proportional increases in the intensity of effort.

6. The case studies presented here represent an environmental situation characteristic of a particular latitudinal range and climatic regime. Results from southern British Columbia should be directly relevant to bullfrog invasions in Europe, northern Asia, western United States, and possibly southern South America. It would be helpful to have comparative data sets from subtropical and tropical regions where bullfrogs are active year-round and the tadpoles reach metamorphosis within 12 months. Conceivably, a comparable programme in warmer climates with no winter dormant period would move along much faster than in these case studies, in which case site eradication through manual electro-frogging may be achievable in as little as 12 months.

7. The proposition that bullfrog eradication is neither feasible nor practical is contradicted by this study. Furthermore, the technique used is time-efficient, cost-effective, humane, and safe for personnel and the environment.

ACKNOWLEDGEMENTS

Victoria's Capital Regional District (CRD) Water and Parks departments have been consistent supporters of this programme from its inception (2005), through its research and development phase (2006) and on into the implementation of the eradication programme (2007 to present). Funding has also been gratefully received from various municipalities throughout the region including: Langford, Saanich, Highlands, View Royal, Metchosin, and Sooke, and agencies such as the Hartland Landfill and the Swan Lake Christmas Hill Nature Sanctuary. I am also grateful to the Veins of Life Watershed Society and the Highlands Stewardship Foundation who were instrumental in getting this programme off the ground, and the many private citizens who made financial contributions to the programme. I am also indebted to Dr. Alex Peden who provided hand drawn base maps and grateful to my field assistant and collaborator, Kevin Jancowski who commented on the manuscript.

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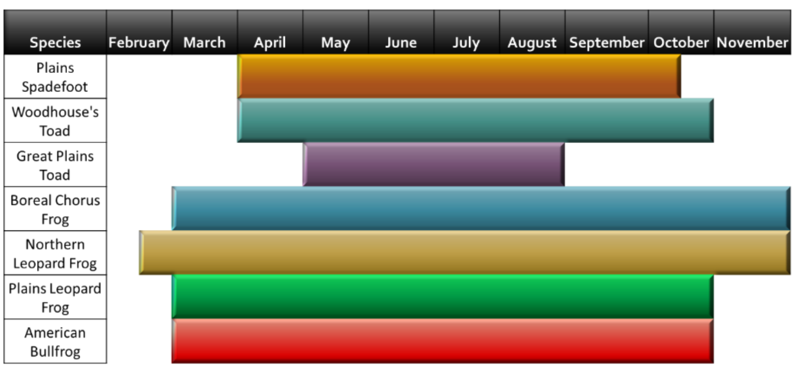
Appendix D: Monitoring Guidelines and FrogWatch USA Protocol

FrogWatch USA Protocol Information: https://www.aza.org/frogwatch-monitoring-protocols

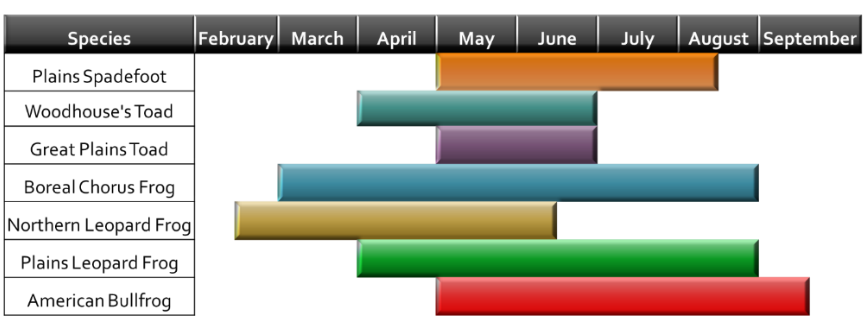
Using auditory surveys to monitor adults at breeding sites is an effective way to gather data to estimate frog species' composition and abundance (Scott and Woodward 1994). This technique is advantageous because it covers a large area, is relatively non-invasive, and can be accomplished by a group of volunteers (Graeter et al. 2013). We recommend an auditory survey-based amphibian volunteer monitoring program supported by additional techniques to be conducted by trained City of Boulder Parks & Recreation staff that target additional life stages (e.g., visual encounter surveys, road surveys, dipnetting and/or funnel trapping). Staff effort will help to offset the limitations of an auditory survey program such as the unequal detectability of species (e.g., pulse breeders call for very short periods, salamanders do not use advertisement calls) or occasional unpredictable calling times that fall outside the monitoring window (e.g. if Northern Leopard Frogs are calling in the afternoon but not after sunset).

We suggest the FrogWatch USA program as the basis for a volunteer call monitoring program. In some years in Colorado, Northern Leopard Frogs begin calling in mid-February, though warm, sunny days in March or April are more common, and in eastern Boulder County most calling is over by the end of April (Hammerson 1999). To get a complete picture of amphibian usage of City of Boulder Parks & Recreation wetlands, we recommend auditory monitoring begin at the start of March and continue until the end of June. This scheme should capture early callers (Northern Leopard Frog) and late callers (American Bullfrog) and everything in-between. We recommend encouraging volunteers to take notes on any observations that fall outside the scope of the FrogWatch program (e.g., hearing a call outside their designated monitoring window or visually observing frogs or tadpoles) as these incidental observations are still useful for planning and management purposes and may inform staff field investigations. The FrogWatch USA program uses a once per week sampling regime – if more frequency is desired, several volunteers may be assigned the same site but a different day of the week to monitor.

Adult surface activity:



Adult calling window:



Appendix E: Cattail Management Guidelines

Source: http://cortland.cce.cornell.edu/agriculture/rural-land-use/ponds/controlling-cattails

Controlling Cattails: How to control cattails in a farm pond

Cattails (Typha latifolia, T. glauca, and T. angustifolia) are native wetland plants with a unique flowering spike and long, flat leaves that reach heights of 4 to 9 feet. They are one of the most common plants in large marshes and on the edge of ponds. Many pond owners view cattails with uncertainty because they have a tendency to grow in thick, nearly impenetrable stands, blocking the view of open water and raising the concern that they will take over and cover a pond. This article describes the various techniques available for cattail control.

Cattails can be desirable in a pond. They provide important wildlife habitat, shelter for birds, food and cover for fish and for the insects they eat. Cattails help protect the banks of a pond from erosion. They intercept and reduce the force of small waves and wind on the shore. The stems catch and slow water and help trap sediment and silt. Cattail roots harbor microorganisms that help break down organic materials. New research shows that cattails can also remove polluting materials from the water surrounding their roots. It is pleasing to see small patches of cattails dispersed around a pond; however, a thick wall of cattails along the shore of the pond makes it hard to enjoy their benefits.

The tendency of cattails to grow in thick stands causes concern for many pond owners. If you want to reduce the amount of cattails in your pond, you should first determine how extensive they are and in what ways they interfere with your enjoyment of the pond. This will help you decide which approach will work for you.

Under the right conditions, cattails can grow and spread vigorously. The pollinated flowers develop into fluffy seed heads, blowing across a pond in autumn breezes. Just as commonly, cattails spread through their root system. The thick, white roots, called rhizomes, grow underground near the edge of ponds and in shallow swales. As long as the water is not too deep, the cattails feast off the open sunshine and abundant water, storing a large amount of food in the root system. In fact, cattails at the edge of pond can grow faster than fertilized corn in a field! The dense foliage and debris from old growth makes it very difficult for competing plant species to grow.

Cattails prefer shallow, flooded conditions and easily get established along a pond shoreline or in waters one to 1.5 feet or less in depth. When unimpeded however, the cattail beds will expand and can extend their hefty rhizomes well out into pond surface, actually floating above much deeper waters. Cattails need to have "wet feet" during most of the growing season.

If you want to control cattails, you will need to disrupt the root system through cutting, hand-pulling, dredging, flooding, freezing, or chemical herbicides. One treatment is seldom sufficient. However, if your timing is good, you can successfully control cattails without chemicals with only a few work sessions every few years.

Hand-pulling

Hand-pulling cattails is a good preventative measure for controlling cattails. It is much easier to pull cattails out of the pond when they are young, rather than at full height. Grasp a cattail at the base of the plant, trying to wrap your fingers around the roots. Slowly pull the plant and the white root out of the soil and cast it onto the shore of the pond. Proceed onto the next plant until you have cleared out the area as completely as possibleyou wish. The murky water will settle in a few days. Keep an eye on the area you cleared for new cattail growth. The pulled cattails will compost very easily if mixed with wood chips and other brown composting materials.

Mowing and Cutting

Timing is everything if you decide to mow or cut your cattails. Cutting them in May stimulates growth, so wait until late summer if you are only going to cut once. If you cut the cattails below the water line two or three times in a season, very few cattails will grow back the following year. Your cutting will have deprived the roots of their important food source and reduced the amount for storage. Winter cutting will have very little effect on the food in the roots of the plant.

You should cut or mow your cattails with shears, a gas-powered weed trimmer, or another safe, sharp cutting tool. Do not use electrical tools near ponds. Cut the cattails as close to, or under, the water line, removing as much of the leaf blade as possible. Rake or pile the leaves away from the pond or add them to your compost pile. Cattail leaves make excellent, durable canes for chairs, mats, and other home crafts. A brush hog attachment on a tractor can be used only if the pond bank is stable and safely sloped. Do not operate heavy tractors on a dike.

Dredging

Some pond owners resort to dredging to remove cattails. The removal of the cattails and the soil they grow in is very disruptive to a pond, but can be more permanent solution to cattail control. The dredging activity should increase the depth at the edge of a pond to a point where cattails are unlikely to grow back (18 – 24"). Dredging is best done when the pond level is lowered below the level where the work will take place. Avoid scooping out pond water, plants, and soil all at the same time. If the water line is lowered, the work can be done with a small bulldozer or backhoe by a qualified operator. Dredging creates an underwater shelf. Be aware that this sudden drop-off near the shore creates a drowning hazard for young children.

Flooding / Freezing

Many ponds are built with water control devices. These are useful mechanisms when controlling cattails and other pond plants. To control cattails, reduce the water level during the growing season for mowing or hand pulling. Alternatively, you can partially freeze the roots if the water level is drawn down in the fall and left low during the coldest weather. Dropping the water level too low may result in oxygen depletion for over wintering fish. Some ponds may refill slowly in spring depending on weather conditions. Avoid dropping the water level late in the fall as many pond animals will have already buried themselves in the mud for the winter and could die of exposure. In some ponds, the water level can be raised above cattail growth, making it difficult for the plants to obtain oxygen. Flooding must be carefully controlled to keep pond dikes stable.

Combining methods

The methods of cattail control noted above can be combined for more effective treatment. For example, regular mowing, combined with freezing, can eliminate cattails almost completely. Pond owners should plan their cattail control in advance, taking into account seasonal weather, wildlife uses, and disposal of cut or dredged material.

Use of Chemical Herbicides

Some pond owners seek quick remedies for pond plant problems through the use of aquatic herbicides (Rodeo, AquaPro, Reward, for example)*. Only "aquatic" herbicides can be used in ponds. It is illegal to use a chemical for pond plant control unless it is specifically labeled for that purpose. In the case of cattails, the label should include the word "cattail" or the botanical name "Typha spp." If you are in doubt, ask a qualified advisor or contact the manufacturer. Fish, swimmers, and other pond users can be seriously harmed if herbicides are used improperly. In many cases, aquatic herbicides contain restrictions regarding swimming, fishing, and watering livestock. They can be much more expensive than the other control options.

The amount of chemical herbicide to use, and directions for application are listed on the label of the product. In some cases, a non-ionic surfactant or dye can be mixed to improve performance of the herbicide and reduce over spraying. Follow label directions regarding personal protection, spray drift, and appropriate weather conditions for application.

In New York State, all aquatic chemical treatments require a NYS Department of Environmental Conservation permit. Contact your regional DEC office and ask for the "aquatic herbicide permit application." If your completed application is approved, you must show proof of having the permit before purchasing and applying aquatic herbicides. You may wish to hire a professional pesticide applicator that is certified in the category "Aquatic Vegetation" to apply chemical herbicides according to your plans.

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Written by Jim Ochterski, Cornell Cooperative Extension South Central New York Agriculture Team, and reviewed by Rebecca Schneider, with research from Ohio State University Extension, The Nature Conservancy, the US Fish and Wildlife Service, and the Cornell University Department of Natural Resources. April 2003.

Appendix F: Raw Data (See attached excel sheet)