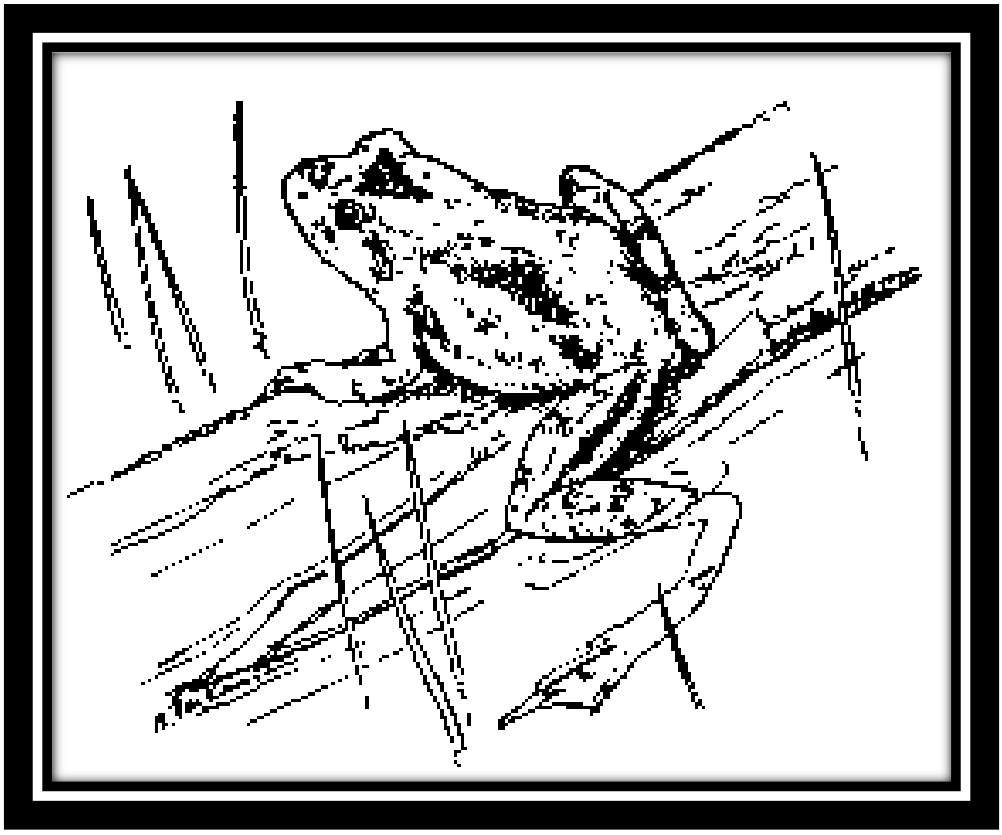
Recovery Plan for New York State Populations of the

Northern Cricket Frog (*Acris crepitans)*



Division of
Fish, Wildlife & Marine Resources

NEW YORK STATE OF OPPORTUNITY | Department of Environmental Conservation

RECOVERY PLAN FOR NEW YORK STATE POPULATIONS OF THE

NORTHERN CRICKET FROG

(*Acris crepitans*)

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Executive Summary

Status

Northern cricket frogs occur throughout most of the eastern half of the United States, but are declining in as many as 17 states. In New York State they are listed as an endangered species and the distribution of northern cricket frogs has historically been limited to the lower Hudson Valley, Long Island, and Staten Island. Northern cricket frogs were extirpated from Long Island by the 1930s and from Staten Island by the 1970s. The reasons for the declines are unclear, and are likely a combination of factors at each site. In the 1990s, northern cricket frogs were documented from 26 distinct sites in New York State, which likely represented northern cricket frogs from five remaining metapopulations. The majority of these sites (22 sites) were resurveyed during the breeding seasons in 2009-2011 and northern cricket frogs were only detected at 7 of those sites. These seven sites likely represent frogs from only four remaining metapopulations in New York State.

Threats

It is not entirely clear what is causing the decline of northern cricket frog populations. A number of potential causes have been suggested including: habitat loss and degradation, chemical pollutants, pesticides, non-native species, pathogens, climate change, and ultraviolet radiation. It is likely that each of these, or a combination of these, may be responsible for the loss of individual populations. Amphibian populations tend to fluctuate naturally, with many individuals present during years with favorable conditions and localized extirpations during years with unfavorable conditions. Northern cricket frogs likely function at a metapopulation, or population of populations, scale where the habitat of these localized extirpations is re-colonized by nearby populations when conditions are again favorable. A metapopulation can persist for long periods of time as long as dispersing individuals can move between sites through suitable habitat. So while localized extirpations may be caused by a variety of reasons, one key to long term sustainable populations is to maintain the habitat connections between sites of suitable northern cricket frog habitat.

Recovery Strategy components:

- Protect and manage remaining populations and habitats.
- Protect suitable and unoccupied habitats and facilitate the colonization of these sites by northern cricket frogs.
- Research critical data gaps on the conservation biology of the northern cricket frogs that will assist in an efficient recovery.
- Develop and support partnerships to facilitate recovery.
- Proactively incorporate climate change predictions into management alternatives to give northern cricket frogs the opportunity to flourish in a changing climate.

Recovery Objectives

The northern cricket frog will be considered for delisting in the State of New York when:

1) At least two metapopulations in each of at least three recovery units, plus one isolated and robust population in each recovery unit, demonstrate long-term persistence. Long-term persistence must be demonstrated through a scientifically sound and biologically meaningful monitoring program.
2) Aquatic breeding habitats of these metapopulations are protected.
3) Additional habitat needed for overwintering, metapopulation connectivity, recolonization and dispersal is protected.
4) Threats and causes of decline have been identified, and reduced or eliminated. The causes of decline must remain diminished without the protections afforded by State endangered species listing.

A variety of actions are required to implement the recovery strategy. These activities are organized as monitoring, management, research and outreach tasks. Priority tasks include:

- Develop a monitoring protocol to determine the distribution and abundance of northern cricket frogs in New York State. This protocol should be scientifically rigorous and designed to determine if a specific metapopulation is robust and persisting long term as well as provide feedback to success of other management actions to allow for adaptive management.
- Protect suitable, but unoccupied, northern cricket frog habitat. This habitat currently has limited regulatory protection so protection must come by other methods. Particular emphasis should be placed on areas within 3 miles of extant populations, especially in the Taconic Foothills (Climate Change Adaptation) Recovery Unit.
- Restore and protect degraded aquatic habitats in close proximity to extant or suitable northern cricket frog breeding habitat.
- Identify suitable habitat in all recovery units, and highlight areas that will continue to provide suitable habitat under projected climate change scenarios.
- Determine if extirpated sites still contain suitable habitat for the northern cricket frog.

  If suitable habitat exists, consider re-introducing an experimental population at the site. Experimental populations should only be re-introduced at formerly occupied sites and should contain an extensive monitoring plan. This monitoring plan should be designed to monitor abundance of the species at the site over time AND determine causes of decline if they occur. Extirpated sites at lands owned by NYS-Office of Parks, Recreation, and Historic Preservation (OPRHP) should be given priority for consideration.

- Explore the development of a "conservation bank." The bank(s) could be modeled after the conservation banks developed by the USFWS and the State of California under close oversight by the NYS Department of Environmental Conservation. The bank(s) would be privately funded endeavors that buy and sell conservation credits awarded for actions that implement specific recovery tasks identified in this plan.

Introduction

The northern cricket frog (*Acris crepitans*) occupies most of the eastern United States, but populations are declining in as many as 17 states, and may be extirpated from many areas (Burdick and Swanson 2010, Conant and Collins 1998, Gamble 2008, Lannoo 2005, McCallum and Trauth 2003a, 2004). Declines have been occurring in New York since the 1930s and populations continue to decline, particularly in the northern fringe of their range (Gray and Brown 2005, Reeder et al. 2005). In New York State, the species was listed as Threatened in 1983 and upgraded to Endangered status in 1999 (Gibbs et al. 2007). The decline of northern cricket frogs coincides with worldwide decreases in amphibian populations (Wake 1991, Stuart et al. 2004). Of the 5,743 known amphibian species in the world, nearly a third (32%) are known to be threatened or extinct (IUCN et al. 2008). Because of their abundance and importance in the ecosystem, it is paramount that amphibians such as the northern cricket frog are conserved (Wake 1991). Here, we detail the pertinent biology of northern cricket frogs, threats to their continued existence, and strategies for their recovery in the state of New York.

Natural History

Taxonomic Status

The northern cricket frog is a member of Hylidae, a large family of frogs (approximately 635 species) that occurs on every continent except Antarctica (Conant and Collins 1998). Five genera of hylids occur in eastern North America, including tree frogs (*Hyla*, *Osteopilus*, and *Smilisca*), cricket frogs (*Acris*), and chorus frogs (*Pseudacris*) (Conant and Collins 1998). Within *Acris*, two species: the northern cricket frog (*A. crepitans*) and southern cricket frog (*A. gryllus*) are currently recognized (Conant and Collins 1998, Rose et al. 2006, Gamble et al. 2008). *Acris crepitans* has three subspecies, including Blanchard's (*A. c. blanchardi*), northern (*A. c. crepitans*), and coastal (*A. c. paludicola*) cricket frogs, but there is debate over the validity of the subspecies (Conant and Collins 1998, Gray et al. 2005, McCallum and Trauth 2006, Rose et al. 2006, Gamble et al. 2008). Based upon morphological data, McCallum and Trauth (2006) suggested that *A. c. blanchardi* and *A. c. crepitans* should not be considered separate subspecies. However, Hamilton (2008) suggested that the subspecies distinctions were valid, although overlap between them was noted. Moreover, based on a genetic analysis, Gamble et al. (2008) suggested that Blanchard's cricket frog should be considered a separate species (*A. blanchardi*), and that *A. c. paludicola* should not receive a subspecies designation (suggested it should be within *A. blanchardi*). Similarly, Rose et al. (2006) failed to genetically differentiate between *A. c. blanchardi* and *A. c. paludicola*, but suggested that *A. c. paludicola* still receive subspecies recognition because of behavioral and morphological differences. There may be differences between frogs referred to as *A. c. blanchardi* and *A. c. crepitans* but play a similar ecological role and have similar life histories (M. McCallum, U. of Missouri, personal communication). Because of a limited amount of previous research on *A. c. crepitans* (the subspecies inhabiting New York), and the similarity between subspecies, much of the biological information presented here is based on research of *A. c. blanchardi*.

Physical Description

Northern cricket frogs are small (16-38 mm in length, 1.5-2.5 g in weight) frogs, with females being slightly larger than males (Wright and Wright 1949, Pyburn 1958, Burkett 1969, Capranica et al. 1973, Nevo 1973, O'Neill 2001, Dickson 2002, Hamilton 2008). Body size varies regionally, with the smallest frogs occurring in the moister areas of the range (northeastern, south-central, and southeastern states) and larger sizes in the drier, western areas (Nevo 1973). Dorsal color ranges from brown to olive-green and gray, with a polymorphic stripe (gray, green, or red), and occasional green spots (Pyburn 1961, Gray 1983, Gray and Brown 2005). Interestingly, cricket frogs may be able to change their dorsal coloration (Pyburn 1961, Gray 1983). Ventrally, northern cricket frogs are white or cream colored, and males have a yellow vocal sac (Gray and Brown 2005). The head is blunt, and possesses a dark triangle between the eyes (Conant and Collins 1998). The skin is thin and well vascularized, warty dorsally, and granular ventrally (Conant and Collins 1998, Beasley et al. 2005, Gray and Brown 2005). The hind limbs are short. The toes have extensive webbing while the back of the thigh has an irregular dark stripe. The anal tubercles are ≥0.5 mm in diameter (Dundee and Rossman 1989, Conant and Collins 1998, Gray and Brown 2005, Micancin and Mette 2009).

Range

The northern cricket frog is distributed throughout most of the eastern half of the United States from southeastern New York south to Georgia, Alabama, and the Florida panhandle, west to western Texas and southeastern New Mexico, and north to southeastern South Dakota (Figure 1). *A. c. crepitans* occupies the eastern portion of the range including New York, mid-Atlantic, and southeastern states. Blanchard's cricket frogs (*A. c. blanchardi*) occupy the western edge of the range, including the mid-west and plains states, with a transition zone from *A. c. crepitans* to *A. c. blanchardi* occurring in Tennessee, Arkansas, and eastern Texas. The coastal cricket frog (*A. c. paludicola)* only occurs in extreme southeastern Texas and southwestern Louisiana (Figure 1).

Breeding Biology

The timing of the breeding season varies geographically, largely due to differences in air and water temperature (Pyburn 1958, Blair 1961, Burkett 1984). In the southern extent of their range, male northern cricket frogs begin calling as early as the end of January or early February, whereas in northern areas calling doesn't begin until late April or May (Pyburn 1958, Blair 1961, Johnson and Christiansen 1976, Gray 1983, Burkett 1984, Dickinson 1993, McCallum et al. 2011). In New York, peak calling is between the end of May and the middle of July (Gibbs et al. 2007).

At the beginning of the calling season, males only call during the day, but as the temperature increases calling becomes more frequent at night, lasting until 2-3 am (Blair 1961, Burkett 1984, Perrill and Shepherd 1989, Dickson 2002). Typically, the calling lasts until July or early August in northern areas (Johnson and Christiansen 1976, Perrill and Magier 1988, Dickinson 1993), with the majority of oviposition occurring in June (McCallum et al. 2011).

The breeding call of male northern cricket frogs is a series of "gicks" or "clicks," which increases in rate through the call, and varies in the number and length of notes (Perrill and Shepherd 1989, Conant and Collins 1998, Kime et al. 2004, Gray et al. 2005, Micancin and Mette 2009,

Micancin et al 2012). The breeding call is used to attract females, and in aggressive interactions with other males, during which the call is slightly modified (Perrill and Shepherd 1989, Kime et al. 2004).

Northern cricket frogs can breed in nearly any permanent body of freshwater, including lakes, ponds, rivers, and streams (Burkett 1984, Dickinson 1993, Gray and Brown 2005). However, breeding is uncommon along large lakes and rivers, vernal pools, and in polluted areas (Dickson 2002, Gray and Brown 2005). Northern cricket frog breeding habitat range-wide and particularly in New York, tends to have shallow water, floating mats of aquatic vegetation, shores with gently sloping banks that are muddy, limited canopy cover, and is at least partly surrounded by forest (Burkett 1984, Dickinson 1993, Greenwell et al. 1996, Beasley et al. 2005, Gray and Brown 2005, Lehtinen and Skinner 2006). In New York, calling males (indicating potential breeding habitat) also have been observed in man-made irrigation ponds for apple orchards (Alvin Breisch, NYSDEC personal communication). Males call from vegetation on the water's edge, on pond banks, and on floating and emergent vegetation (Pyburn 1958, Perrill and Shepherd 1989, Dickinson 1993, Gray and Brown 2005).

After a female chooses a male, he mounts and clings to her in a position known as amplexus. In doing so, the male is able to fertilize the eggs as she releases them. Females lay 200-400 eggs, usually individually or in small clusters of up to 7 eggs, but as many as 15 eggs have been recorded in a single cluster (Livezy 1950, Smith 1961, Van Gorp 2001, Gray and Brown 2005). Females probably lay multiple clutches during the breeding season, but mostly during a one month span (McCallum et al. 2011). Usually, eggs are attached to vegetation at depths of 0.5-2.0 cm below the water's surface, but may also be placed on the water bottom, or float on the surface (Van Gorp 2001, Dickson 2002, Gray and Brown 2005). Field observations of northern cricket frog eggs in New York suggest that clusters are typically of 2 or 3 eggs and can occur in lily depressions and pools within floating vegetative mats (J. Westerveld, New York Natural History Council (NYNH), personal communication).

Developmental Biology

Eggs hatch 3-4 days after fertilization, and the larval (tadpole) stage lasts 29-90 or more days (Burkett 1969, Pyburn 1961, Dundee and Rossman 1989). Northern cricket frog tadpoles are relatively large (up to 46 mm total length), usually have a distinct black tip, light colored throat, mottled or reticulated tail musculature, dorsolateral eyes, a slightly depressed body, and 2 rows of teeth on the upper and lower lips (Orton 1952, Burkett 1969, Altig 1970, Gray and Brown 2005). Northern cricket frog tadpoles remain in the water, where they prefer shallow areas, and feed primarily on algae until metamorphosis (Johnson 1991). Aquatic and floating vegetation is an important aspect of tadpole habitat, because it provides cover, thereby increasing survival (Beasley et al. 2005).

Metamorphosis typically occurs in July and August, but can vary depending on the date of spawning (Pyburn 1958, Burkett 1984, Gray and Brown 2005). Metamorphosis takes 2 days, and newly transformed juveniles are 10-15 mm in length (Wright and Wright 1949, Dickson 2002). After metamorphosis, juveniles emerge from the water, and grow rapidly, in some areas reaching adult size in two months (Gray 1983, Burkett 1984, Dundee and Rossman 1989). However, full size is usually not attained until after a period of rapid growth following spring emergence from hibernation (Gray 1983, Burkett 1984, McCallum et al. 2011). The growth rate of northern cricket frogs may have a large impact on their population (Diana et al. 2000). By growing quickly,

northern cricket frogs can avoid predation, and metamorphose earlier and at larger sizes, thereby increasing chances of survival, minimizing time spent in the water (and exposure to pollutants within it), and potentially increasing reproductive success (Johnson 1991, Diana et al. 2000).

Non-breeding biology

Adult and juvenile northern cricket frogs are semi-aquatic, and typically spend the summer months within a relatively small area around the water bodies in which they breed (Burkett 1984, O'Neill 2001, Walvoord 2003). Northern cricket frogs move around the periphery of their breeding waterbody, and may move among neighboring waters (Burkett 1984, O'Neill 2001). Movements between ponds as distant as 1.3 km have been recorded (Gray 1983). During and shortly after rain, northern cricket frogs travel much greater distances, including movements away from water (Pyburn 1958, Burkett 1984, O'Neill 2001).

In fall, northern cricket frogs tend to be found further from their native pond, which may represent dispersal, foraging, or searches for wintering areas (O'Neill 2001). In New York, a second annual peak of northern cricket frog observations (the first being during the breeding season) is reported in September and October (NYS Herp Atlas, unpublished data). Frogs observed in this time period are often found at considerable distances from breeding locations, utilizing a wide variety of habitats including dry uplands. In New York, northern cricket frogs are commonly observed at distances of more than 300m from the nearest breeding habitat at both Little Dam and Glenmere Lakes (Hecht et al. 2008, McKean and Kenney 2012, Jason Tesauro and Mike Nowicki unpublished report 2008, Jay Westerveld, NYNH, personal communication). A single tagged individual was also documented moving 515m away from the breeding habitat at Glenmere Lake in the fall of 2009 (McKean and Kenney 2012). While in the uplands, northern cricket frogs are often found near habitat that provides them some cover (Kenney et al. 2012), and around Glenmere Lake they may prefer the Japanese stiltgrass *Microstegium vimineum* (Jay Westerveld NYNH, personal communication).

Northern cricket frogs may be observed in any month of the year when temperatures are warm, especially in the southern portion of their range (Gray 1971, Pyburn 1958). In the northern portion of their range, northern cricket frogs are typically active until late October, November, or early December (depending on the location and weather conditions), and thereafter overwinter until spring (Gray 1971, Johnson and Christiansen 1976). The most common overwintering strategies for frogs in northern climates include: overwintering at the bottom of a waterbody, finding moderately moist shelter in a terrestrial site, (usually those using this strategy have some degree of freeze tolerance), or to become fossorial in a dry terrestrial site (Irwin et al. 1999, Irwin 2005). These strategies require special adaptations: tolerance of hypoxic conditions, freezing of tissues, or the ability to burrow below the frost line. Laboratory experiments have demonstrated that northern cricket frogs do not have these adaptations, and must have a different overwintering strategy (Irwin et al.1999, Irwin 2005, Swanson and Burdick 2010). Therefore, northern cricket frogs are believed to overwinter terrestrially near their breeding habitat, in cracks, depressions, or burrows excavated by other animals (Gray 1971, Irwin et al. 1999, McCallum and Trauth 2003b, Irwin 2005). However, only a few hibernacula have been located in the wild. These few reports suggest that hibernacula are in close proximity to water, are 3-10 cm below the soil surface, and may be communal (Gray 1971, Irwin et al. 1999, McCallum and Trauth 2003b, Swanson and Burdick 2010). In New York, however, hibernacula distant from water may be more common and

have been reported at distances greater than 85m from aquatic habitat in both anthropogenic (Westerveld, 2012) and natural burrows (Kenney et al. 2012).

Northern cricket frogs emerge from hibernation in late March or early April (Gray 1971, Johnson and Christiansen 1976, Gray 1983). Gray did not find overwintering to be a major source of mortality (Gray 1983, Gray et al. 2005), but Burkett (1984) reported a very low (5%) spring recapture rate of frogs originally captured in fall, and accordingly suggested that many frogs may not survive the winter. In New York, northern cricket frogs are not observed as frequently in dry uplands in spring as compared to fall. Instead, observations are more frequent in aquatic habitats such as stream corridors, vernal pools, and water filled tire ruts (McKean and Kenney 2012, Alvin Breisch NYSDEC, Jack Hecht HDR, and Jay Westerveld, NYNH, personal communications, Jason Tesauro and Mike Nowicki, unpublished data).

Adult and juvenile northern cricket frogs are gape-limited opportunistic predators that forage throughout the day and night (Johnson and Christiansen 1976, Labanick 1976, Gray and Brown 2005). The vast majority of prey items are insects and other arthropods (e.g., spiders and centipedes), but gastropods, isopods, crayfish, and annelids also are preyed on (Hartman 1906, Jameson 1947, Gehlbach and Collette 1959, Bayless 1969, Johnson and Christiansen 1976, Labanick 1976, Burkett 1984, Dickson 2002) and attempted cannibalism exists (McCallum et al. 2001). In New York, northern cricket frogs have been observed eating springtails (Jay Westerveld NYNH, personal communication). Occasionally, plant material has been reported in cricket frog digestive tracts, but it may be incidentally consumed (Jameson 1947, Dickson 2002). While aquatic, aerial, and ground dwelling prey are taken, most prey tends to be terrestrial or littoral, and items are taken in proportion to their availability. Aquatic organisms are taken less frequently regardless of abundance. (Johnson and Christiansen 1976, Labanick 1976, Dickson 2002).

Due to their small size, cricket frogs are consumed by a variety of predators, including aquatic spiders, bullfrogs (*Rana catesbeiana*), fish, snakes, turtles, birds, and mammals (Burkett 1984, Perrill and Magier 1988, Gray and Brown 2005). When approached by a predator, northern cricket frogs typically hop in a zigzag pattern, dive into the water, and swim in a semi-circle back to shore (Gray and Brown 2005). However, they may also hop into thick vegetation, or dive into the water and hide (Dickson 2002, Johnson 2003) particularly in the spring (Westerveld NYNH, personal communication). When captured, cricket frogs may play dead when captured and will also emulate this behavior after conducting a series of zigzag jumps (McCallum 1999, McCallum 2011). Largely due to heavy predation, cricket frog populations decrease tremendously between metamorphosis and the next breeding season (Gray 1983, Burkett 1984, Gray and Brown 2005). As a result, mean life expectancy is about 4 months, and individuals born the previous year are mostly eliminated from the population by October (Gray 1983, Burkett 1984, O'Neill 2001, Gray and Brown 2005). However, occasionally adults survive to a second breeding season (Gray 1983, McCallum et al. 2011).

Status Assessment

Population Status and Distribution

Northern cricket frogs occur throughout most of the eastern half of the United States, but are declining in as many as 17 states (Conant and Collins 1998, McCallum and Trauth 2003a, Gray and Brown 2005). Such declines may have begun as early as the 1930s and continue to occur, leading to fragmented and isolated populations, particularly on the northern edge of the species'

range (Gray and Brown 2005, McCallum and Trauth 2004, Reeder et al. 2005). Declines or extirpation of regional populations have been reported in northeastern Illinois (Mierzwa 1998), northern Indiana (Brodman and Kilmurry 1998, Minton 1998), northern Iowa (Hemesath 1998), northern Ohio (Ohio Frog and Toad Calling Survey 2005), Pennsylvania (Pennsylvania Fish and Boat Commission 2010), southern Michigan (Michigan Natural Features Inventory 2007), southern Minnesota (Minnesota Department of Natural Resources 2010), South Dakota (Fischer et al 1999), West Virginia (Dickson 2002, West Virginia Department of Natural Resources 2003), Wisconsin (Jung 1993, Casper 1998, Mossman et al. 1998, Paloski et al. 2010), Ontario, Canada (Oldham 2003), and Mexico (Gray and Brown 2005). Although northern cricket frog populations may be declining in many areas, in others (particularly in the center of their range) their populations appear stable and abundant (Davis et al. 1998, Hemesath 1998, Gray and Brown 2005, Micancin et al. 2012).

In New York State, the distribution of northern cricket frogs has historically been limited to the lower Hudson Valley and Long Island (New York Natural Heritage Program (NYNHP), 2010; Gibbs et al. 2007; American Museum of Natural History(AMNH), see Figure 2). Historic records from Richmond (NYNHP), Queens, and Nassau (AMNH) counties were not water body specific, so are shown as large highlighted areas. Northern cricket frogs were extirpated from Suffolk County by the 1930s and from Richmond County by the 1970s (Gibbs et al. 2007). No records of cricket frogs are known to exist after 1921 in Queens and Nassau counties. In the 1990s, northern cricket frogs were documented from 26 distinct sites in New York State, which likely represented northern cricket frogs from five remaining metapopulations (Figure 3). Most of these sites (22 sites) were resurveyed during the breeding seasons in 2009-2011 and northern cricket frogs were only detected at seven of those sites. These seven sites likely represented frogs from only four remaining metapopulations in New York State (Figure 3).

Threats to the Species

Northern cricket frogs face many perils to their continued persistence, including anthropogenic, biotic, and abiotic threats. Accordingly, many causative agents have been suggested for observed declines in their populations. Because northern cricket frogs are declining throughout their range, any single factor is unlikely to be the cause. Instead, many potentially interacting threats are likely at fault. Due to geographical variation, the reason for a decline in a particular region is not necessarily the cause of the disappearance of northern cricket frogs from another area. Therefore, although we present many possible threats to the species, not all of them may truly have a significant impact on the persistence of northern cricket frogs in the state of New York.

Habitat loss and degradation

For northern cricket frogs, other amphibians, and other rare species, habitat loss and degradation may be the greatest threat to their continued existence. For example, after comparing amphibian surveys conducted in west-central and northern New York in 1973-1980 to surveys in the same wetlands in 2001-2002, Gibbs et al. (2005) concluded that although persisting populations were relatively stable, populations have decreased over the previous 30 years due to habitat loss. Because of their complex habitat requirements (e.g., semi-permanent wetlands for breeding and tadpole development, and forested habitats providing adequate food and wintering

areas for juveniles and adults), northern cricket frogs may be particularly vulnerable to changes in their habitat.

Northern cricket frogs also seem to have a metapopulation structure; a functional population that is actually a collection of smaller, spatially discrete populations within a habitat complex that supports them all. This collection of different habitats in close proximity to each other would then make the entire metapopulation of northern cricket frogs more resilient. If, for example, a breeding site becomes temporarily unsuitable (e.g. all the vegetation is removed) the frogs will be lost from that site very quickly. However, if the migratory habitat connections to that site remain intact, nearby northern cricket frogs may eventually recolonize the site when the habitat at the breeding site becomes suitable again (e.g. the vegetation returns). A likely explanation for the loss of northern cricket frog metapopulations is the simultaneous loss of multiple required habitats. This habitat loss results in both the loss of specific small populations and also serves to destabilize the entire metapopulation.

Upland habitat

In New York, the threats associated with conversion of upland habitats to residential and commercial development are particularly intense. The human population in the three counties (Dutchess, Orange, and Ulster) that contain extant northern cricket frog populations has increased by 45.9% between 1970 and 2008 (U.S. Census Bureau 2009). The urbanization of the landscape in the Hudson River Valley has also increased, with a 29% increase in urbanization in the region between 1982 and 1997 (Pendall 2003). The habitat conversion around two former sites on Long Island is shown in Figures 4 and 5.

Residential, commercial, transportation and infrastructure development within areas utilized by the northern cricket frog can negatively impact northern cricket frog populations. During construction, the conversion of habitat may result in the direct mortality of northern cricket frogs on the site. After construction, the new land use may also negatively affect migratory and wintering habitat of the northern cricket frog. Mortality during migratory movements can also increase by increasing frog vulnerability to predation by subsidized predators and direct mortality by vehicular traffic and property maintenance. Available wintering habitat can also be lost if wintering areas are converted to homes sites and infrastructure. The extirpation of Blanchard's cricket frogs from some areas has been directly attributed to habitat loss or degradation (Lehtinen 2002). Also, if dispersal corridors become degraded, populations can become more fragmented and isolated, ultimately increasing the risk of extirpation (Green 2005).

Forest management practices also have the potential to threaten northern cricket frogs in upland habitat. Activities that disturb the soil within the upland areas utilized by northern cricket frogs have the potential to kill frogs in their hibernacula. Additionally, poor sediment management has the potential to degrade the water quality at breeding habitat.

Direct mortality by vehicles is another threat to northern cricket frogs. In areas where roads pass in close proximity to breeding habitat, frogs can be killed by passing vehicles, especially during spring and fall dispersal. All terrain vehicle (ATV) use is another potential source of direct mortality that is particularly threatening in spring, when rutted trails collect water, thereby attracting northern cricket frogs moving between winter and summer habitats.

Northern cricket frogs may also be impacted by a number of other upland activities that may affect their migratory or winter habitat including, but not limited to, blasting, mineral extraction, oil/natural gas drilling, and changes in agricultural practices.

Aquatic habitat

A variety of activities that manipulate water levels and degrade water quality at breeding sites may have detrimental impacts on northern cricket frog populations by decreasing the quantity or quality of available breeding and nursery habitat. Activities that alter wetland habitats near northern cricket frog populations (e.g. draining, filling, ditching), or alter surface hydrology (e.g. stream diversion, or impoundment construction) all may negatively impact northern cricket frog breeding habitat.

The management of aquatic plants in northern cricket frog breeding habitats poses a significant threat to the continued persistence of northern cricket frogs. These management actions take a variety of forms, are commonly implemented throughout southern New York, and are largely undertaken to remove plants that impact recreational activities, water supplies, or aesthetics. Aquatic vegetation management potentially affects northern cricket frogs by killing and/or removing vegetation that the frogs rely on for breeding, egg laying and tadpole development. This section will detail some of the more common threats to aquatic habitats, but it should be emphasized that any aquatic vegetation removal in northern cricket frog breeding habitats may negatively affect northern cricket frog populations.

Management techniques for aquatic vegetation in New York State include: mechanical, physical, biological, and chemical controls (NYSFOLA 2009). Mechanical control methods include hand or mechanical harvesting, rotovating, and dredging. Physical control methods include benthic barriers, shading, and water level manipulation. All of these types of control methods have the potential to severely impact northern cricket frog breeding and nursery habitat.

Biological controls involve introducing plant pathogens, or herbivorous insects or fish (NYSFOLA 2009). In New York State, only sterile (triploid) grass carp can be stocked for use in aquatic plant control. The effect of grass carp stocking varies widely, but there is a tendency for complete eradication of aquatic vegetation, or very little control (Bonar et al. 2002). This tendency may result from preferential feeding, as grass carp consume the most palatable plants first, and therefore may avoid the target species (Bain 1993). Because northern cricket frogs use aquatic vegetation for many aspects of their life cycle, they are highly sensitive to reduction of aquatic vegetation by grass carp. Accordingly, Blanchard's cricket frogs were extirpated from a wetland in Iowa following the introduction of grass carp (Leja 1998). Milfoil moths (*Acentria ephemerella*) and milfoil weevils (*Euhrychiopsis lecontei)* have been used in New York State to control the growth of Eurasian watermilfoil (*Myriophyllum spicatum).* The use of these biological controls may be appropriate in water bodies that contain northern cricket frogs since they may control the spread of an exotic plant that may reduce the abundance of native vegetation required by the northern cricket frog.

In New York State, six herbicides (diquat, endothall, fluridone, glyphosate, triclopyr, and 2,4-D) have been registered for aquatic plant control (NYSFOLA 2009). These herbicides are available in a variety of formulations and brand names. In studies focused on determining the effects of diquat, the results are mixed. A few studies (i.e., Cooke 1977, Dial and Dial 1987) failed to document a negative impact, whereas others have recorded slower growth, alteration of pigmentation, body abnormalities, and high mortality following exposure (Anderson and Prahlad 1976, Bimber and Mitchell 1978). Similarly, studies of glyphosate are somewhat contradictory. Glyphosate-based formulations have been reported to cause body malformations, decreased swimming ability, smaller size at metamorphosis, slower development, delayed metamorphosis,

gonadal abnormalities, and high mortality (Howe et al. 2004, Wojtaszek et al. 2004, Cauble and Wagner 2005, Relyea 2005). However, Howe et al. (2004) reported that glyphosate itself, and some formulations did not cause significant mortality or other effects. Triclopyr formulations have been reported to cause abnormal avoidance behavior, increased frequency of malformations, delayed hatching, and mortality for some species, whereas others have displayed no or limited detrimental effects (Edginton et al. 2003, Wojtaszek et al. 2005, Chen et al. 2008). Heggstrom (2009) documented a decrease in tadpole length after exposure to 2,4-D. But, no effects on behavior, frequency of abnormalities, survival, wet weight, or timing of metamorphosis were observed by Heggstrom (2009) or Cooke (1972).

For species with a tolerance to direct toxicity of aquatic herbicides, the indirect effects may impact the population more substantially. For example, the removal of aquatic vegetation would reduce habitat quality, potentially reduce egg and tadpole survival (by reducing the amount of cover), and ultimately decreasing carrying capacity and population size. Also, herbicide exposure can alter the abundance and species composition of the periphyton, phytoplankton, and zooplankton communities (Hestand and Carter 1978, Perez et al. 2007, Relyea 2009). In doing so, tadpole food availability and quality can be negatively affected, potentially leading to slower growth and development, higher mortality, and decrease the number of larvae that metamorphose (Johnson 1991, Wojtaszek et al. 2005, Relyea 2009). Further, one hypothesis to explain the decline in New York implicates the aerial spraying of pesticides to control for gypsy moth populations. This hypothesis suggests that this spraying resulted in the loss of two important prey groups, Collembola spp. and Delphacidae spp., from waterbodies where northern cricket frogs have since been lost (Westerveld 2012).

Algal blooms are common problems on New York State lakes, and are controlled through physical, chemical, and biological mechanisms (NYSFOLA 2009) that also have the potential to negatively affect northern cricket frogs and their habitats. Algaecides, the most common form of algal control, are generally copper-based (NYSFOLA 2009). Copper sulfate is the most commonly used algaecide, and is used on more than 300 lakes and ponds in New York State (NYSFOLA 2009). In frogs, exposure to excessive copper levels has been demonstrated to cause malformations, slower growth, decreased body size, later metamorphosis, reduced swimming speed, slower reaction time, and mortality (Kaplan and Yoh 1961, Lande and Guttman 1973, Chen 2007). Additionally, copper sulfate can cause indirect effects by killing rooted aquatic vegetation (New York State Department of Environmental Conservation 1981).

Other chemical pollutants

In addition to herbicides and algaecides that are applied directly to the aquatic environment, other chemicals (e.g., insecticides, fungicides, and terrestrial herbicides) may threaten amphibian populations, particularly in agricultural areas. These chemicals can enter the aquatic system by drifting in following terrestrial application, or from runoff from adjacent lands. Northern cricket frogs may have a tolerance to low levels of environmental contamination (Ferguson and Gilbert 1967, Greenwell et al. 1996). But studies on northern cricket frogs and other amphibians have demonstrated that, at higher concentrations, chemical pollutants may alter sex ratios, cause intersexuality (having mixed sexual tissue, or the presence of a complete testis and ovary in the same individual), increase rates of parasite infection, modify behavior, decrease hatching success, slow growth and development, decrease size, cause body malformations, and directly cause mortality (Fleming et al. 1982, Ankley et al. 1998, Greenwell et al. 1996, Hatch and Burton 1998,

Reeder et al. 1998, Marco and Blaustein 1999, Diana et al. 2000, Beasley et al. 2005, Bridges and Semlitsch 2005a, Gray and Brown 2005, Reeder et al. 2005). Chemicals known to cause deleterious effects on amphibians include: ammonia (Jofre and Karasov 1999), atrazine (Greenwell et al. 1996, Diana et al. 2000), carbaryl (Zaga et al. 1998, Boone and Semlitsch 2001, Bridges and Semlitsch 2005b), chloronil (Anderson and Prahlad 1976), dichlone (Anderson and Prahlad 1976), diazinon (Relyea 2009), fluoroanthene (Hatch and Burton 1998), methoprene (Ankley et al. 1998), nitrite (from nitrogen based fertilizers; Marco and Blaustein 1999), parathion (Fleming et al. 1982), polychlorinated biphenyls (PCBs; Reeder et al. 2005), and polychorlinated dibenzofurans (PCDFs; Reeder et al. 2005), among others. Problematically, chemical pollutants can work synergistically with other biotic (e.g., density, and presence of predators) and abiotic (e.g., UV radiation, pH, and other chemicals) factors, causing more severe effects (Hatch and Burton 1998, Zaga et al. 1998, Boone and Semlitsch 2001, Relyea 2005).

Aquatic and terrestrial herbicides are typically sold as formulations that include the active ingredient, and inactive ingredients (e.g., surfactants, compatibility agents, and acidifiers) which may increase the efficacy of the herbicide (Tatum 2004). Depending on the target species and herbicide used, surfactants may be necessary for the herbicide to work effectively (Wojtaszek et al. 2004, Siemering et al. 2008). Problematically, the toxicity of surfactants and other inactive ingredients are not tested as stringently as active ingredients, but are frequently more toxic to amphibians (Mann and Bidwell 1999, Howe et al. 2004, Tatum 20004, Trumbo 2005, Siemering et al. 2008). In some cases, such as in glyphosate-based herbicides with the surfactant polyethoxylated tallowamine (POEA), the surfactant may be the primary cause of toxicity of the formulation (Howe et al. 2004).

Climate Change

Climatic factors affect northern cricket frog populations. For example, natural phenomena such as periodic drought have been reported to cause population declines, and even lead to extirpation (Lannoo et al. 1994, Skelly et al. 1999). The full effects of climate change on northern cricket frog populations in New York State are difficult to predict, because they (and other species in decline) may be more sensitive to climate change due to a lower adaptive capacity to exploit changes in their habitat.

There is a high degree of confidence among climate scientists in the direction of change in some aspects of climate in the Northeastern US (e.g. temperature will increase, extreme rainfall events) but these scientists have less confidence in the amount of change over time (Rosenzweig et al 2011). In some areas of climate modeling, such as projections of average precipitation change, there is still a high degree of uncertainty. This uncertainty creates challenges for predicting the effects on northern cricket frogs. A model that was developed to evaluate the impacts of climate change on cricket frogs (McCallum 2010) predicted catastrophe for cricket frogs. This analysis highlighted the fact that while it may seem that some climate changes may be beneficial to cricket frogs, the interaction among seasonal changes in rainfall and air temperature may actually be detrimental.

Given the uncertainty surrounding both the timing and likelihood of some climatic changes and the impacts these may have on northern cricket frogs, this recovery plan focuses on the two aspects of climate change that are most likely to occur and most likely to affect northern cricket frogs: increasing mean annual temperature and increased frequency of extreme precipitation events (Hayhoe et al. 2006, Karl et al. 2009). Theoretically, increasing annual mean temperature and

precipitation would make environmental conditions in New York State similar to current conditions in more southerly locations, where northern cricket frog populations are larger and more stable. As a result, northern cricket frog populations in New York could increase, and their range may extend northward. However, dispersal corridors allowing for colonization of more northern latitudes may no longer be available because of extensive development. The inability to disperse to new areas would become particularly problematic if locations in which northern cricket frogs currently persist become uninhabitable (or at least decline in habitat quality) due to changing climatic conditions, natural succession, or other factors. Thus, dispersal corridors must be considered on both a metapopulation and larger landscape scale.

Climate change will likely result in modification of the timing of the northern cricket frog life cycle. For example, the breeding season will likely occur earlier in the year, as has been documented for the frog *Rana temporaria* in Finland (Terhivuo 1988), and *Epidalea calamita* and *Pelophylax* kl. *esculentus* in England (Beebee 1995). Similarly, warmer temperatures will probably lead to earlier spring emergence, which would be problematic if northern cricket frogs become active before their food sources become available, or if warmer spring days stimulates emergence, and overnight temperatures decrease to below the frog's thermal tolerance.

Parasites and Pathogens

Parasites and pathogens including trematodes (flatworms), cestodes (tapeworms), nematodes (roundworms), protozoans, bacteria, viruses (particularly iridoviruses such as *Ranavirus* spp.), and fungi are known to infect amphibians, and may contribute to population declines (Burkett 1984, Carey 1993, Kiesecker and Blaustein 1997, Daszak et al. 1999, Carey et al. 2003, Bridges and Semlitsch 2005a, Sutherland 2005). Parasitic infestations can negatively affect cricket frogs by causing decreased body size, malformations and skin lesions, limited reproductive success, and decreased survival (Beasley et al. 2005, Burkett 1984, Greenwell et al. 1996, Kiesecker and Blaustein 1997, Johnson and Lunde 2005, McCallum and Trauth 2007). Many pathogens occur naturally in low densities, but their effects may be amplified when the population is stressed by other factors (Kiesecker and Blaustein 1997). Pathogens have likely been spread locally and across the globe from the pet trade, biological supply companies, introduction of non-native species, and the use of infected bait by fishermen (Jankovich et al. 1997, Carey et al. 2003).

Trematodes, such as *Ribeiroia ondatrae* and *Manodistomum syntomentera*, parasitize cricket frogs, and can cause malformation of the hind limbs (particularly having supernumerary limbs) when *metacercariae* (the encysted stage of the trematode life cycle) embed in developing tissues, and disrupt limb development (Sessions and Ruth 1990, Johnson and Lunde 2005). Because malformations cause difficulties in locomotion, affected frogs probably have higher predation rates (Johnson and Lunde 2005). Human activity, particularly through eutrophication, may be altering wetlands so that they are favorable to snails (often the first host of trematodes), potentially leading to increased rates of frog infestation, and consequently contributing to the apparent increase in frequency and severity of body malformations in amphibians (Sessions and Ruth 1990, Johnson and Lunde 2005).

Parasitism of amphibians by chytrid fungi causes a disease known as chytridiomycosis (Berger et al. 1998, Daszak 1998, Pessier et al. 1999). Although the disease was discovered relatively recently, it has been linked to mass mortalities in many different regions of the world including the United States, Europe, Australia, and South America (Berger et al. 1998, Milius 1998, Carey et al. 1999, Lips 1999, Pessier et al. 1999, Carey et al. 2003). The fungus infects

keratinized regions of the body, particularly the skin of adults and juveniles, but also the mouthparts of tadpoles (Berger et al. 1998, Dazcak 1998, Lips 1999). The disease leads to malformation of tadpole mouthparts, and abnormal posture, lethargy, loss of the righting reflex, and eventually death of adults and juveniles (Berger et al. 1998, Daszak et al. 1999, Lips 1999). Death probably results from impaired respiration and osmoregulation by the skin, or from toxins released by the fungus (Berger et al. 1998, Dazcak 1998). Northern cricket frogs are known to contract the disease (Steiner et al. 2007, Beasley et al. 1995) which is known to be widely distributed in the northeastern United States (Milius 1998, Longcore et al. 2007).

The highly contagious disease known as "red-leg" is caused by the bacterium *Aeromonda hydrophila* (Nyman 1986). Red leg disease has been linked to the extirpation of some populations of boreal toads (*Bufo boreas boreas*) and a mass mortality event of *Lithobates sylvatica* in a pond in Rhode Island (Nyman 1986, Carey 1993). *A. hydrophila* is likely to infect cricket frogs (Hunsaker and Potter 1960).

Ultraviolet radiation

A worldwide phenomenon that may be affecting northern cricket frogs and other amphibians, is increased levels of ultraviolet radiation (UV) resulting from depletion of the ozone layer (Blaustein et al. 1998). Ultraviolet radiation, particularly UV-B (290-320 nm), can cause body malformations, darkening of the skin, abnormal swimming behavior, and decreased hatching success (Grant and Licht 1995, Ankley et al. 1998, Blaustein et al. 1998, Hatch and Burton 1998, Zaga et al. 1998, Van Gorp 2001). Many amphibian species provide their eggs with protection from UV by having eggs with a coating of jelly surrounding them, by having melanin on the dorsal surface, or by laying eggs in large clusters, giving the eggs in the center of the cluster additional protection (Grant and Licht 1995, Van Gorp 2001). Water depth, turbidity, dissolved organic carbon levels, and emergent and submerged vegetation also can provide protection from UV radiation (Grant and Licht 1995, Corn 1998, Crump et al. 1999). Because northern cricket frogs lay eggs in small clusters near the surface of the water, and without a protective jelly layer, they are highly susceptible to the effects of UV radiation (Van Gorp 2001). However, many studies on the effects of UV on amphibians have observed no deleterious effects (Corn 1998), or impacts only at intensities that greatly exceed natural exposures (Crump et al. 1999).

Non-native species

The introduction of non-native species can affect northern cricket frog populations in a variety of ways. Introduced predatory fish can negatively affect northern cricket frogs through predation, by limiting the amount of suitable habitat, and preventing dispersal if the fish occupies water bodies along dispersal corridors (Fellers and Drost 1993). Accordingly, Pilliod and Peterson (2001) reported higher amphibian populations at fishless sites in comparison to areas with introduced trout species. Similarly, Blair (1951), Bradford (1989), and Fellers and Drost (1993) have suggested that non-native fish caused local extirpation of amphibians. Smallmouth (*Micropterus dolomieu*) and largemouth bass (*M. salmoides*) are known predators of northern cricket frogs (Burkett 1984), and in New York are native only to the tributaries of the St. Lawrence and Great Lakes (outside the range of northern cricket frogs) (Smith 1985). But, bass were introduced into much of New York State many decades ago (and hence are now naturalized in many ecosystems) through direct introduction by humans, and indirectly by building of the Erie

Canal (Smith 1985). At northern cricket frog breeding sites in which bass have become naturalized, northern cricket frogs may have adapted to bass predation. However, further introduction of bass or other fish species in suitable northern cricket frog habitat should be discouraged. The crayfish *Orconectes virilis* has been reported to decrease the abundance of aquatic vegetation and associated invertebrate fauna, and kill juvenile and adult frogs, thereby contributing to the decline of Chiricahua leopard frogs (*Lithobates chiricahuensis*) in Arizona, where the crayfish is non-native (Fernandez and Rosen 1996). *O. virilis* occurs naturally in New York (Crocker 1957), but non-native crayfishes could cause similar devastation. The introduction of non-native fish, amphibians, invertebrates, or other organisms could impact northern cricket frogs through competition for resources, increased predation, or cause cascading trophic effects that could influence northern cricket frog food sources or habitat.

Assessment of current conservation efforts

Research and monitoring

A population viability assessment, demographic sensitivity analysis, and metapopulation analysis were conducted on northern cricket frogs using the best information available (Appendix C). This analysis revealed that small fluctuations in reproductive success and overwintering mortality resulted in extreme shifts in long-term population stability. This emphasizes the importance of management tasks in this recovery plan that positively impact reproductive success or overwintering survival. The metapopulation analysis demonstrated that isolated small populations (50 individuals) have little chance of long-term survival. It also found that larger populations are more stable, but have potential problems associated with inbreeding depression and catastrophic events would result in regional extirpation. The complete analysis is attached as Appendix C, and recommends a management strategy that maintains a compromise between population size and geographic proximity of populations.

One common feature of robust populations of northern cricket frogs in New York State is a relatively large undisturbed area around the shoreline of breeding sites. These undisturbed areas undoubtedly contain the upland habitats required by northern cricket frogs. Research that can define the habitat requirements of northern cricket frogs, and how far they extend from breeding sites, is critical for conservation planning to ensure that essential upland habitat is protected. Therefore, recent research by the NYSDEC has been focused on defining the upland habitats utilized by the northern cricket frog and is summarized in a DEC report (McKean and Kenney, 2012).

Another potential threat to northern cricket frogs in New York, and amphibians worldwide, is Chytridiomycosis, a disease suspected in the declines of amphibian populations. The NYSDEC and the Wildlife Conservation Society are currently undertaking a pilot study to survey for the presence of this fungus at a number of currently and formerly occupied northern cricket frog sites in New York.

Surveys of calling males are commonly used to monitor the presence of northern cricket frog populations. Although the use of some breeding areas may be limited or non-existent in some years, this remains the best tool to monitor the presence of northern cricket frogs in particular breeding areas. The problem of limited breeding in some years can be mitigated by: 1) monitoring sites for multiple years; and 2) by conducting calling surveys using methods outlined in Appendix

B. While ad hoc surveys have been periodically conducted by the Department, a more formal and consistent methodology needs to be developed to monitor extant northern cricket frog populations.

Regulatory protections

Range-wide conservation status can be loosely summarized by an assessment of the protection status of northern cricket frogs, in the various states in which they occur. Generally, in the core of their range the northern cricket frog has the same protection as other herpetofauna in the state. However, on the periphery of its range, a number of states have identified the northern cricket frog as in need of additional protection. The species is listed as endangered in Minnesota, Pennsylvania, Wisconsin and New York. It is listed as threatened in Michigan, and a species of special concern in Colorado and Indiana.

In New York State, all native amphibians, including northern cricket frogs, are listed as "protected wildlife," and therefore people shall not kill, wound, pursue, take, buy, sell, offer for sale, transport, or possess native herpetofauna except as provided for by Environmental Conservation Law or DEC regulations or both. Conservation law does provide for an open season for frogs and some turtles, but not for northern cricket frogs. In addition, northern cricket frogs are listed as an endangered species in New York State (6 NYCRR Part 182.5). This listing means that the species is threatened with extirpation from New York State and is afforded additional protection (ECL 11-0535). Northern cricket frogs may not be taken (e.g. hunted or captured, interference with their essential behaviors or habitats), imported, transported, sold, or possessed without a permit from the Department. While these permits have been used as a mechanism to mitigate project related impacts on northern cricket frogs, the rarity, vulnerability and ecological uniqueness of this species strongly limits the scope of viable mitigation, and there may be instances where mitigation of impacts is not possible. Furthermore, the federal Lacey Act prohibits the trade of any state-protected species, such as northern cricket frogs, that have been illegally taken, transported, or sold.

These protections mean that activities that are reviewed by the Department as part of the State Environmental Quality Review process are evaluated to ensure that the activities do not result in the "take" of a northern cricket frog. The screening process used by the Department to identify potentially harmful projects is included in Appendix A. Occupied habitat of the species is considered the breeding habitats identified by the New York Natural Heritage Program, as well as the upland habitat surrounding these sites that is necessary for the survival and perpetuation of northern cricket frogs, including all habitats associated with hibernation, feeding, sheltering, migration, and movement. Our best current scientific understanding suggests that these upland behaviors generally take place within 1500 feet of known breeding locations. At specific sites, these behaviors may extend farther, or not as far, as this guideline.

Recovery Strategy

Recovery Goal: To establish a long-term self-sustaining population of northern cricket frogs within New York State, resulting in the recovery and delisting of the species in NYS.

To meet this goal, the northern cricket frog must reach a population level and have sufficient habitat throughout its historical range to provide for the long-term persistence of the species. Specific criteria are established in the Recovery Objectives section.

Recovery Strategy components:

- Protect and manage remaining populations and habitats.
- Protect suitable and unoccupied habitats and facilitate the colonization of these sites by northern cricket frogs.
- Research critical data gaps on the conservation biology of the northern cricket frog that will assist in an efficient recovery.
- Develop and support partnerships to facilitate recovery.
- Proactively incorporate climate change predictions into management alternatives to give northern cricket frogs the opportunity to flourish in a changing climate.

Protect and manage remaining populations and habitats

While the northern cricket frog remains listed as endangered in New York, it will be afforded the protections outlined in the Regulatory Protections section above. For the species to be truly recovered, it is necessary to demonstrate that northern cricket frogs have persisted long-term without the protections afforded by a state endangered classification. While we work toward recovery of the species, all existing protections will remain in place until delisting.

Specific recovery tasks for this component of the strategy include actions that will improve the protection of northern cricket frogs while listed as endangered and actions that would be necessary for the species to remain protected after delisting. These tasks are listed in the Management tasks section.

Protect suitable and unoccupied habitats and facilitate the colonization of these sites by northern cricket frogs

For the northern cricket frog to fully recover in New York State it must demonstrate long-term viability at more sites than it is currently known to occur. It is, therefore, important to protect suitable habitats where northern cricket frogs are not currently present. These suitable habitats, and connections among these sites and known populations, must be identified and protected. This protection must remain in place without the protection of endangered species regulation.

Some of these sites with suitable habitat may be appropriate for the re-introduction of northern cricket frogs. Northern cricket frogs may be considered for re-introduction at formerly extant sites if suitable habitat still remains, northern cricket frog habitat requirements are understood, and a funded and scientifically sound protocol is in place to monitor northern cricket frog abundance and assess potential causes of decline at any re-introduction site.

Research critical data gaps on the conservation biology of the northern cricket frog that will assist in an efficient recovery

There are large gaps in our understanding of basic northern cricket frog ecology. Focus will be on gaps that have the most direct relationship to the conservation biology of the species, where results can be applied toward the protection of the species. The research questions that we feel are most likely to elicit results that will immediately benefit the recovery of the northern cricket frog are listed below in the Research Tasks section.

Develop and support partnerships to facilitate recovery

Recovery of the northern cricket frog in New York State is a challenging task. This will only be accomplished through the concerted effort of a wide variety of organizations. The development and support of partnerships that work together toward a common goal is necessary for success. Specific tasks that address this strategy are identified in the Outreach Tasks section.

Proactively incorporate climate change predictions into management alternatives to give northern cricket frogs the opportunity to flourish in a changing climate

Sound planning for the future of the northern cricket frog should incorporate elements that consider the potential impacts of climate change. Elements that are included in this plan were developed largely from guidance developed in the National fish wildlife and plants climate adaptation strategy (USFWS et al. 2013). A key step for planning for the northern cricket frog in New York State will be to identify the potential impacts, opportunities and vulnerabilities to the species that arise from likely future scenarios of climate and other drivers.

Given the uncertainty surrounding future climate scenarios, this recovery plan gives priority to recovery actions that will be effective in both current and future climate conditions. The action that will most directly affect the recovery of the northern cricket frog is the protection of lands (aquatic and upland) that provide, or will provide in the future, critical habitat to the northern cricket frog. Land protections must occur at both the scale of the individual metapopulation (some breeding areas may become unsuitable and other unsuitable areas in close proximity may become suitable) and at a larger landscape scale for metapopulations to flourish at more northern climates and allow colonization of new habitats. Specific climate change adaptation recovery actions are identified in the recovery tasks section.

Recovery Units

This strategy will be implemented on a geographic basis. Four recovery units have been identified (Figure 6). Recovery units were determined based on the historical range of the NORTHERN CRICKET FROG and the ecozones developed by the NYSDEC habitat inventory unit (Ozard 1991, Dickinson 1983). Recovery units were developed because the known threats and recovery actions differ within the species' New York range. The priority threat in each recovery area is identified in the description of each recovery unit (below) and specific recovery tasks identify the units in which they are appropriate.

<u>Hudson Highlands (HH)</u>

This recovery unit contains portions of Orange, Rockland, Putnam and Dutchess counties. The unit contains rough and stony topography with a large portion of the unit greater than 700 ft. in elevation. The underlying geology is composed of a complex assortment of igneous and metamorphic rock.

There is one known extant metapopulation in this recovery unit located in and around Little Dam Lake in the OPRHP owned Sterling Forest of Orange County. This unit has at least 7 sites that are likely extirpated (Ashman Pond, Lake Stahahe, Green Pond, Island Pond, Echo Lake, Little Long Pond, and Lake Kanawauke). The recent loss of the Island Pond metapopulation in

this unit is a concerning example of the challenges faced by northern cricket frogs in New York. As recently as 1988, this was a robust population, but had declined by 1990 and has since disappeared. (No northern cricket frogs observed in at least 8 surveys between 1992 and 2011). This extirpation occurred despite the fact that no known management changes occurred at the breeding site during the time period, and the surrounding extensive state parkland experienced no noticeable change in land use.

Major threats to recovery of the species in this unit are a lack of suitable numbers of northern cricket frogs to re-establish suitable sites and damage to aquatic habitat at suitable sites. As the Island Pond example demonstrates, however, the most important threats to the recovery of northern cricket frogs may not yet be understood.

Coastal Lowlands and Manhattan Hills (CL)

This recovery unit encompasses Suffolk and Nassau counties, as well as the five counties that comprise New York City. This recovery unit lumps two ecozones: coastal lowlands and Manhattan Hills. The coastal lowlands can be characterized as very low elevation glacial outwash. The Manhattan Hills are areas of more rolling hills extending from the Hudson River to slightly higher elevations than the coastal lowlands. Large portions of both areas are densely developed for commercial or residential uses.

Northern cricket frogs were found in this area around the turn of the twentieth century on Staten Island and the eastern end of Long Island. They are believed to be extirpated from this unit and no northern cricket frogs have been documented in this unit since the 1970s.

The most significant threat to recovery of the species in this unit is the lack of remaining suitable habitat.

Hudson Limestone Valley (HV)

This recovery unit contains portions of Greene, Columbia, Dutchess, Ulster and Orange counties. This unit is a subdivision of the Mid-Hudson ecozone that is composed of areas dominated by limestone. The mid-Hudson ecozone is a lower elevation zone, with the majority of the region at elevations of less than 500ft. The region's topography is generally flat to rolling hills and composed of northern hardwoods.

Several robust populations remain in this area including Glenmere Lake / Black Meadow Creek, Lily Lakes and Pine Hole Bog. Northern cricket frogs in this unit have also been found along a number of stream corridors, in a man-made mitigation marsh and irrigation ponds in apple orchards.

The most significant threats to recovery in this unit are upland and aquatic habitat loss and degradation.

Taconic Foothills (TF) – Climate change adaptation unit

This recovery unit is comprised of the portions of the Taconic Foothills ecozone that occur in Dutchess and Columbia counties. The ecozone was limited to these counties to represent areas that are in relatively close proximity to existing or recent known northern cricket frog populations. Elevation in this zone is generally between 400 and 800 ft. The landscape is dominated by rolling hills and current or former agricultural operations.

This recovery unit contains a recently discovered metapopulation of northern cricket frogs in New York State, discovered in 1993. These 3 populations are potentially part of one larger

metapopulation and are the only northern cricket frogs documented on the east side of the Hudson River.

This unit has the greatest potential for colonization of new sites in a changing climate. The major threats in the zone are upland and aquatic habitat loss and degradation.

Recovery Objectives

The northern cricket frog will be considered for delisting in the State of New York when:

1. At least two metapopulations in each of at least three recovery units, plus one isolated and robust population in each recovery unit, demonstrate long-term persistence. Long term persistence must be demonstrated through a scientifically sound and biologically meaningful monitoring program.
2. Aquatic breeding, dispersal, and overwintering habitats of these metapopulations are protected.
3. Habitat needed for metapopulation connectivity and recolonization of recovered habitats is also protected.
4. Threats and causes of decline have been identified, and reduced or eliminated. The causes of decline must remain diminished without the protections afforded by State endangered species listing.

These criteria are described as a guide for when the species may be considered for a change of listing, but the northern cricket frog will not be automatically delisted if the criteria are met. The status of all of New York's species is periodically reviewed by the Department to determine if changes in the status, or additions or deletions to the list are warranted. These decisions are based on the best scientific information available at the time, and consider progress toward recovery objectives in that determination.

Recovery Tasks

The recovery tasks identified in this plan will minimize or eliminate the threats listed in this plan and help meet the Recovery Objectives for the species. Actions listed as recovery tasks in this plan are generally considered to provide a conservation benefit to the species. If a task is specific to one or more recovery units, the units are listed in parentheses after the task.

Monitoring Tasks

Develop a monitoring protocol to determine the distribution and abundance of northern cricket frogs in New York State. This protocol should be scientifically rigorous and designed to determine if a specific metapopulation is robust and persisting long term as well as provide feedback to the success of other management actions to allow for adaptive management.

Conduct calling surveys to locate extant populations of northern cricket frogs.
High priority: Historic locations, especially in (CL, HV)
High priority: Suitable habitat within 0.5 miles of extant breeding sites.

Priority: Suitable habitat in all recovery units

Management Tasks – for immediate completion

Continue to protect occupied northern cricket frog habitats that support essential behaviors of the northern cricket frog. Specific actions are spelled out in the "Regulatory Protections" section. Habitat protection may also be provided through:

- Fee title acquisition for conservation purposes
- Acquisition of conservation easements
- Development and implementation of landowner management plans

Protect suitable, but unoccupied, northern cricket frog habitat. This habitat currently has limited regulatory protection so protection must come by other methods. Particular emphasis should be placed on areas within 3 miles of extant populations, especially in the Taconic Foothills (Climate Change Adaptation) Recovery Unit. Habitat protection may be provided through:

- Fee title acquisition for conservation purposes
- Acquisition of conservation easements
- Development and implementation of landowner management plans

Update recovery plan every five years to incorporate new information gathered on this poorly understood species.

Reduce or eliminate direct mortality by motor vehicles (including ATV's) where mortality is known or likely to occur.

Restore and protect degraded aquatic habitats in close proximity to extant or suitable northern cricket frog breeding habitat.

Management Tasks – require additional research/planning before implementation.

Determine if sites with extirpated populations still contain suitable habitat for northern cricket frogs (HV,CL,HH) . If suitable habitat exists, consider re-introducing an experimental population at the site. Any re-introduction will require a monitoring plan. This monitoring plan should be designed to monitor abundance of the species at the site over time AND determine causes of decline if they occur. Care should be taken to ensure that the introduction of an experimental population does not significantly impact the source population. Extirpated sites at lands owned by NYS-OPRHP should be given priority for consideration.

Maintain and restore corridors needed for dispersal between populations.

- For each metapopulation, identify and prioritize potential dispersal corridors based on observed dispersal distances, geography and environmental conditions.
- For each metapopulation, prepare and implement a plan to maintain or restore priority dispersal corridors.

Eliminate contaminants that negatively impact northern cricket frog populations. Particular emphasis should be placed on chemicals commonly used for aquatic plant management.

Minimize impact of diseases that threaten northern cricket frog populations from all recovery units.

Research Tasks

Threats and causes of decline are still poorly understood. One of the main actions recommended by this plan is to determine the causes of population declines in New York northern cricket frogs.

Identify suitable habitat in all recovery units, and highlight areas that will continue to provide suitable habitat under projected climate change.

Determine habitat types utilized by northern cricket frogs for overwintering at several locations.

Determine migratory corridors utilized by northern cricket frogs at extant sites.

Evaluate migratory corridors and wintering habitats to determine if there are similarities in habitat types or movement patterns utilized by different northern cricket frog metapopulations.

Quantitatively document population level threats to each extant northern cricket frog metapopulation.

Determine demographic parameters necessary to reduce uncertainty surrounding population viability analysis including, but not limited to, age of first reproduction, production, mortality, catastrophe impacts, and dispersal.

Update and revise Population Viability Analysis (Appendix III) as research and monitoring data specific to New York become available.

Determine the occurrence level and threat posed by infectious diseases, including Chytridiomycosis and ranavirus.

Conduct a climate change vulnerability assessment for the northern cricket frog.

Determine if extirpated sites still contain suitable habitat for northern cricket frog, and assess future suitability under various climate change projections.

Design a scientifically meaningful protocol to monitor population levels and sources of decline at experimental population sites.

Determine the type and quantity of submerged and emergent vegetation necessary for northern cricket frogs breeding and developmental biology.

Develop occupancy modeling that will identify areas where northern cricket frogs may be extant, but unknown to science, in New York State. Modeling should identify the best places, times and methods to locate northern cricket frog populations.

Identify contaminants that negatively impact northern cricket frog populations. Particular emphasis should be placed on chemicals commonly used for aquatic plant management.

Outreach Tasks

Develop Best Management Practices(BMP) for northern cricket frog habitat. These practices can be distributed to private landowners in suitable northern cricket frog habitat. These BMP's should identify easy steps homeowners can take to improve cricket frog viability in their area.

Develop a public education campaign about aquatic habitats. This campaign should be developed by people or organizations skilled in public outreach. The Lake Champlain Basin Program's campaign on eutrophication could serve as a model. The message should highlight the importance of vegetated aquatic habitats (especially habitats with boggy mats) and the mitigation of threats to those habitats.

Explore the development of a "conservation bank." The bank(s) could be modeled after the conservation banks developed by the USFWS and the State of California under close oversight by the Department. The bank(s) would be privately funded endeavors that buy and sell conservation credits awarded for actions that implement specific recovery tasks identified in this plan.

Develop a way to deliver information to county, town and village governments about northern cricket frogs. Information should be delivered to environmental conservation commissions and planning boards at an interval frequent enough to keep up with the frequent turnover of these bodies. Information provided should include where the northern cricket frog is found within the entity, when to contact the Department, and Best Management Practices for potential, but unoccupied, northern cricket frog habitat.

Identify other potential, but currently underutilized, local partners in the vicinity of northern cricket frog populations (NGOs, watershed groups, land trusts, etc.)

Update the NYSDEC northern cricket frog "Fact sheet"

Literature Cited

Altig, R. 1970. A key to the tadpoles of the continental United States and Canada. Herpetologica 26:180-207.

American Museum of Natural History (AMNH). 2013. AMNH Herpetology Collections Database. http://www.amnh.org/our-research/vertebrate-zoology/herpetology/database.

Ankley, G. T., J. E. Tietge, D. L. DeFoe, K. M. Jensen, G. W. Holcombe, E. J. Durhan, and S. A. Diamond. 1998. Effects of ultraviolet light and methoprene on survival and development of *Rana pipiens*. Environmental Toxicology and Chemistry 17:2530-2542.

Bain, M.B. 1993. Assessing impacts of introduced aquatic species: grass carp in large systems. Environmental Management 17(2):211-214.

Bayless, L. E. 1969. Ecological divergence and distribution of sympatric *Acris* populations (Anura: Hylidae). Herpetologica 25:181-187.

Beasley V, Faeh S, Wikoff B, et al: 1995, Evidence for a potential role of pesticides in population declines of the cricket frog (Acris crepitans). Proc Sec Environ Toxic Chem World Congr 1995:94.

Beasley, V. R., S. A. Faeh, B. Wikoff, C. Staehle, J. Eisold, D. Nichols, R. Cole, A. M. Schofthoefer, M. Greenwell, and L. E. Brown. 2005. Risk factors and declines in northern cricket frogs (*Acris crepitans*). Pages 75-86 *in* M. Lannoo, editor. Amphibian declines: the conservation status of United States species. University of California press, Berkeley and Los Angeles, California.

Beattie, R. C., and R. Tyler-Jones. 1992. The effects of low pH and aluminum on breeding success of the frog *Rana temporaria*. Journal of Herpetology 26:353-360.

Beebee, J. C. 1995. Amphibian breeding and climate. Nature 374:219-220.

Berger, L., R. Speare, P. Daszak, D. E. Green, A. A. Cunningham, C. L. Goggin, R. Slocombe, M. A. Ragan, A. D. Hyatt, K. R. McDonald, H. B. Hines, K. R. Lips, G. Marentelli, and H. Parkes. 1998. Chytridomycosis causes amphibian mortality associated with population declines in the rain forests of Australia and Central America. Proceedings of the National Academy of Science, USA. 95:9031-9036.

Blair, A. P. 1951. Note on the herpetology of the Elk Mountains, Colorado. Copeia 1951:239-240.

Blair, W. F. 1961. Calling and spawning seasons in a mixed population of anurans. Ecology 42:99-110.

Blaustein, A. R., J. M. Kiesecker, D. P. Chivers, D. G. Hokit, A. Marco, L. K. Belden, and A. Hatch. 1998. Effects of ultraviolet radiation on amphibians: field experiments. American Zoology 38:799-812.

Bonar, S. A., B. Bolding, and M. Divens. 2002. Effects of triploid grass carp on aquatic plants, water quality, and public satisfaction in Washington State. North American Journal of Fisheries Management 22:96-105.

Boone, M. D., and R. D. Semlitsch. 2001. Interactions of an insecticide with larval density and predation in experimental amphibian communities. Conservation Biology 15:228-238.

Bradford, D. F. 1989. Allotopic distribution of native frogs and introduced fishes in high Sierra Nevada lakes of California: implication of the negative effect of fish introductions. Copeia 1989:775-778.

Bridges, C. M., and R. D. Semlitsch. 2005a. Xenobiotics. Pages 89-92 *in* M. Lannoo, editor. Amphibian declines: the conservation status of United States species. University of California press, Berkeley and Los Angeles, California.

Bridges, C. M., and R. D. Semlitsch. 2005b. Variation in pesticide tolerance. Pages 93-95 *in* M. Lannoo, editor. Amphibian declines: the conservation status of United States species. University of California press, Berkeley and Los Angeles, California.

Brodman, R., and M. Kilmurry. 1998. Status of amphibians in northwestern Indiana. Pages 125-136 *in* M. J. Lannoo, editor. Status and conservation of Midwestern amphibians. University of Iowa press, Iowa City, Iowa.

Burdick, S.L. and D.L. Swanson. 2010. Status, distribution and microhabitats of Blanchard's cricket frog *Acris blanchardi* in South Dakota. Herpetological Conservation and Biology 5:9-16.

Burkett, R. D. 1969. An ecological study of the cricket frog, *Acris crepitans*, in northeastern Kansas. Dissertation, University of Kansas, Lawrence, Kansas, USA.

Burkett, R. D. 1984. An ecological study of the cricket frog, *Acris crepitans*. Pages 89-103 *in* R. A. Seigel, L. E. Hunt, J. L. Knight, L. Malaret, and N. L. Zushlag, editors. Vertebrate ecology and systematics- a tribute to Henry S. Fitch. Museum of Natural History, University of Kansas, Lawrence.

Capranica, R. R., L. S. Frishkopf, and E. Nevo. 1973. Encoding of geographic dialects in the auditory system of the cricket frog. Science 182:1271-1275.

Carey, C. 1993. Hypothesis concerning the causes of the disappearance of boreal toads from the mountains of Colorado. Conservation Biology 7:355-362.

Carey, C., N. Cohen, and L. Rollins-Smith. 1999. Amphibian declines: an immunological perspective. Developmental and Comparative Immunology 23:459-472.

Carey, C., A. P. Pessier, and A. D. Peace. 2003. Pathogens, infectious disease, and immune defenses. Pages 127-136 in Amphibian Conservation, R. D. Semlitsch, editor. Smithsonian Books, Washington, D. C.

Casper, G. S. 1998. Review of the status of Wisconsin amphibians. Pages 199-205 *in* M. J. Lannoo, editor. Status and conservation of Midwestern amphibians. University of Iowa press, Iowa City, Iowa.

Cauble, K. and R.S. Wagner. 2005. Sublethal effects of the herbicide glyphosate on amphibian metamorphosis and development. Bull. Environ. Contam. Toxicolology. 75:429-435.

Center for Reptile and Amphibian Conservation and Management. 2010. Blanchard's cricket frog (*Acris crepitans blanchardi*). <http://herpcenter.ipfw.edu/index.htm?http://herpcenter.ipfw.edu/outreach/MWfrogs_toads.htm&2>. Accessed 10 March 2010.

Chen, T. H., J. A. Gross, and W. H. Karasov. 2007. Adverse effects of chronic copper exposure in larval northern leopard frogs (*Rana pipiens*). Environmental Toxicology and Chemistry 26:1470-1475.

Chen, C.Y., K.M. Hathaway, D.G. Thompson, C.L. Folt. 2008. Multiple stressor effects of herbicide, pH, and food on wetland zooplankton and a larval amphibian. Ecotoxicology and Environmental Safety 71:209-218.

Conant, R., and J. T. Collins. 1998. A field guide to the reptiles and amphibians of eastern and central North America. Third edition. Houghton Mifflin Company, Boston, Massachusetts, USA.

Cooke, A.S. 1972. The effects of DDT, Dieldrin and 2,4-D on amphibian spawn and tadpoles. Environmental pollution 3:51-68.

Corn, P. S. 1998. Effects of ultraviolet radiation on boreal toads in Colorado. Ecological Applications 8:18-26.

Crocker, D. W. 1957. The crayfishes of New York State. New York State Museum and Science Service Bulletin 355. The University of the State of New York, Albany, New York, USA.

Crump, D., M. Berrill, D. Coulson, D. Lean, L. McGillivray, and A. Smith. 1999. Sensitivity of amphibian embryos, tadpoles, and larvae to enhanced UV-B radiation in natural pond conditions. Canadian Journal of Zoology 77:1956-1966.

Daszak, P. 1998. A new fungal disease associated with amphibian population declines: recent research put into perspective. British Herpetological Society Bulletin 65:38-41.

Daszak, P., L. Berger, A. A. Cunningham, A. D. Hyatt, D. E. Green, and R. Speare. 1999. Emerging infectious diseases and amphibian population declines. Emerging Infectious Diseases. 5(6): 735-748.

Davis, J. G., P J. Krusling, and J. W. Ferner. 1998. Status of amphibians in Hamilton County, Ohio. Pages 155-165 *in* M. J. Lannoo, editor. Status and conservation of Midwestern amphibians. University of Iowa press, Iowa City, Iowa.

Diana, S. G., W. J. Resetarits Jr., D. J. Schaeffer, K. B. Beckmen, and V. R. Beasley. 2000. Effects of atrazine on amphibian growth and survival in artificial aquatic communities. Environmental Toxicology and Chemistry 19:2961-2967.

Dickinson, N. 1983. Physiographic zones of southern and western New York. NYSDEC manuscript. 9 pp.

Dickinson, R. A. 1993. Northern cricket frog (*Acris crepitans*) survey in Ulster County, New York, 1992. Thesis, Bard College, Annandale-on-Hudson, New York, USA.

Dickson, N. J. 2002. The natural history and possible extirpation of Blanchard's cricket frog, *Acris crepitans blanchardi*, in West Virginia. Thesis, Marshall University, Huntington, West Virginia, USA.

Dundee, H. A., and D. A. Rossman. 1989. The amphibians and reptiles of Louisiana. Louisiana State Press, Baton Rouge, Louisiana, USA.

Edington, A.N., G.R. Stephenson, P.M. Sheridan, D.G. Thompson and H.J. Boermans. 2003. Effect of pH and release on two life stages of four anuran amphibians. Environmental toxicology and chemistry. 22(11) pp 2673-2678.

Fellers, G. M., and C. A. Drost. 1993. Disappearance of the Cascade's frog, *Rana cascadae* at the southern end of its range, California, USA. Biological Conservation 65:177-181.

Ferguson, D. E., and C. C. Gilbert. 1967. Tolerances of three species of anuran amphibians to 5 chlorinated hydrocarbon insecticides. Journal of the Mississippi Academy of Science 13:135-138.

Fernandez, P. J., and P. C. Rosen. 1996. Effects of the introduced crayfish *Orconectes virilis* on native herpetofauna in Arizona. Final Report, IIPAM Project No. I94054 to Heritage Program, Arizona Game and Fish Department.

Fischer, T. D., D. C. Backlund, K. F. Higgins, and D. E. Naugle. 1999. Field guide to South Dakota amphibians. SDAES Bulletin 733. South Dakota State University, Brookings, South Dakota, USA.

Fleming, W. J., D. de Chacin, O. H. Pattee, T. G. Lamont. 1982. Parathion accumulation in cricket frogs and its effects on American kestrels. Journal of Toxicology and Environmental Health 10:921-927.

Gamble, T., P. B. Berendzen, H. B. Shaffer, D. E. Starkey, and A. M. Simons. 2008. Species limits and phylogeography of North American cricket frogs (*Acris*: Hylidae). Molecular Phylogenetics and Evolution 48:112-125.

Gehlbach, F. R., and B. B. Collette. 1959. Distributional and biological notes on the Nebraskka herpetofauna. Herpetologica 15:141-143.

Gibbs, J. P., K. K. Whiteleather, and F. W. Schueler. 2005. Changes in frog and toad populations over 30 years in New York State. Ecological Applications 15:1148-1157.

Gibbs, J.P., A. R. Breisch, P.K. Ducey, G. Johnson, J. L. Behler, and R. C. Bothner. 2007. The amphibians and reptiles of New York State. Oxford University Press, New York, New York, USA. 422pp.

Grant, K. P., and L. E. Licht. 1995. Effects of ultraviolet radiation on life history stages of anurans from Ontario, Canada. Journal of Zoology 73:2292-2301.

Gray, R. 1971. Fall activity and overwintering of the cricket frog (*Acris crepitans*) in central Illinois. Copeia 1971:748-750.

Gray, R. H. 1983. Seasonal, annual, and geographic variation in color morph frequencies of the cricket frog, *Acris crepitans*, in Illinois. Copeia 1983:300-311.

Gray, R. H., and L. E. Brown. 2005. Decline of northern cricket frogs (*Acris crepitans*). Pages 47-54 *in* M. Lannoo, editor. Amphibian declines: the conservation status of United States species. University of California press, Berkeley and Los Angeles, California.

Gray, R. H., L. E. Brown, and L. Blackburn. 2005. Northern cricket frog. Pages 441-443 *in* M. Lannoo, editor. Amphibian declines: the conservation status of United States species. University of California press, Berkeley and Los Angeles, California.

Green, D. M. 2005. Biology of amphibian declines. Pages 28-33 *in* M. Lannoo, editor. Amphibian declines: the conservation status of United States species. University of California press, Berkeley and Los Angeles, California.

Greenwell, M., V. Beasley, and L. E. Brown. 1996. The mysterious decline of the cricket frog. Aquatica 26:48-54.

Hamilton, A. M. 2008. A taxonomic study of the genus *Acris* and the status of *Acris crepitans blanchardi* (Harper), Blanchard's cricket frog, in southern Ohio and western West Virginia. Thesis, Marshall University, Huntington, West Virginia, USA.

Hartman, F. A. 1906. Food habits of Kansas lizards and batrachians. Transactions of the Kansas Academy of Science 20:225-229.

Hatch, A. C., and G. A. Burton Jr. 1998. Effects of photoinduced toxicity of fluoranthene on amphibian embryos and larvae. Environmental Toxicology and Chemistry 17:1777-1785

Hayhoe, K., C.P. Wake, T.G. Huntington, L.Luoy, M.D. Scharts, J. Sheffield, E.F. Wood, B. Anderson, J. Bradbury, A DeGaetano, T.Troy, and D. Wolfe. 2006. Past and future changes in climate and hydrological indicators in the U.S. Northeast. Climate Dynamics.

Hecht, J., A. Breisch, J. Jaycox. 2008. Presentation at the Northeast Natural History Conference. Albany, New York, USA.

Heggstrom, M.J. 2009. The sublethal effects of 2,4-D Dimethylamine on wood frog tadpoles in Saskatchewan. M.S Thesis. University of Saskatchewan. Saskatoon, Saskatchewan, Canada.

Hemesath, L. M. 1998. Iowa's frog and toad survey, 1991-1994. Pages 206-216 *in* M. J. Lannoo, editor. Status and conservation of Midwestern amphibians. University of Iowa press, Iowa City, Iowa.

Howe, C. M., M. Berrill, B. D. Pauli, C. C. Helbing, K. Werry, and N. Veldhoen. 2004. Toxicity of glyphosate-based pesticides to four North American frog species. Environmental Toxicology and Chemistry 23:1928-1938.

Hunsaker, D., and F. E. Potter. 1960. "Red leg" in a natural population of amphibians. Herpetologica 16: 285-286.

Irwin, J. T. 2005. Overwintering in northern cricket frogs (*Acris crepitans*). Pages 55-58 *in* M. Lannoo, editor. Amphibian declines: the conservation status of United States species. University of California press, Berkeley and Los Angeles, California.

Irwin, J. T., J. P. Constanzo, and R. E. Lee, Jr. 1999. Terrestrial hibernation in the northern cricket frog, *Acris crepitans*. Canadian Journal of Zoology 77:1240-1246.

IUCN, Conservation International, and NatureServe. 2008. An Analysis of Amphibians on the 2008 IUCN Red List. www.iucnredlist.org/amphibians.

Jameson, E. W., Jr. 1947. The food of the western cricket frog. Copeia 1947:212.

Jankovich, J. K., E. W. Davidson, J. F. Morado, B. L. Jacobs, and J. P. Collins. 1997. Isolation of a lethal virus from the endangered tiger salamander *Ambystoma tigrinum stebbinsi*. Disease of Aquatic Organsisms 31:161-167.

Jofre, M. B., and W. H. Karasov. 1999. Direct effect of ammonia on three species of North American anuran amphibians. Environmental Toxicology and Chemistry 18:1806-1812.

Johnson, B. K., and J. L. Christiansen. 1976. The food and food habits of Blanchard's cricket frog, *Acris crepitans blanchardi* (Amphibia, Anura, Hylidae). Journal of Herpetology 10:63-74.

Johnson, L. M. 1991. Growth and development of larval northern cricket frogs (*Acris crepitans*) in relation to phytoplankton abundance. Freshwater Biology 25:51-59.

Johnson, S. R. 2003. *Acris crepitans blanchardi* (Blanchard's cricket frog) behavior. Herpetological Review 34:355.

Johnson, P. T. J., and K. B. Lunde. 2005. Parasite infection and limb malformations: a growing problem in amphibian conservation. Pages 124-138 *in* M. Lannoo, editor. Amphibian declines: the conservation status of United States species. University of California press, Berkeley and Los Angeles, California.

Jung, R. E. 1993. Blanchard's cricket frogs (*Acris crepitans blanchardi*) in southwest Wisconsin. Transactions of the Wisconsin Academy of Science 81:79-87.

Kaplan, H. M., and L. Yoh. 1961. Toxicity of copper for frogs. Herpetologica 17:131-135.

Karl, T.R., J.M. Melillo, and T.C. Peterson (eds). 2009. Global Climate change impacts in the United States. Cambridge University Press.

Kenney, G., K. McKean, J. Martin, C. Stearns. 2012. Identification of terrestrial wintering habitat of *Acris crepitans.* Northeastern Naturalist 19(4):698-700.

Kiesecker, J. M., and A. B. Blaustein. 1997. Influences of eggs laying behavior on pathogenic infection of amphibian eggs. Conservation Biology 11:214-220.

Kime, N. M., S. S. Burmeister, and M. J. Ryan. 2004. Female preference for socially variable call characteristics in the cricket frog, *Acris crepitans*. Animal Behaviour 68:1391-1399.

Labanick, G. M. 1976. Prey availability, consumption, and selection in the cricket frog, *Acris crepitans* (Amphibia, Anura, Hylidae). Journal of Herpetology. 10:293-298.

Lande, S. P., and S. I. Guttman. 1973. The effects of copper sulfate on the growth and mortality rate of *Rana pipiens* tadpoles. Herpetologica 29:22-27.

Lannoo, M. J. 2005. Amphibian declines: The conservation status of United States Species. Berkeley: University of California Press. 1094 pp.

Lannoo, M. J., K. L. Lang, T. Waltz, and G. S. Phillips. 1994. An altered amphibian assemblage: Dickinson County, Iowa, 70 years after Frank Blanchard's survey. American Midland Naturalist 131:311-319.

Lehtinen, R. M. 2002. A historical study of the distribution of Blanchard's cricket frog (*Acris crepitans blanchardi*) in southeastern Michigan. Herpetological Review 33:194-197.

Lehtinen, R. M., and A. A. Skinner. 2006. The enigmatic decline of Blanchard's cricket frog (*Acris crepitans blanchardi*): a test of the habitat acidification hypothesis. Copeia 2006:159-167.

Leja, W. T. 1998. Aquatic habitats in the midwest: waiting for amphibian conservation initiatives. Pages 345-353 in Status and Conservation of Midwestern amphibians. M. J. Lannoo, editor. University of Iowa Press, Iowa City.

Lips, K. R. 1999. Mass mortality and population declines of anurans at an upland site in western Panama. Conservation Biology 13:117-125.

Livezy, R. L. 1950. The eggs of *Acris gryllus crepitans* Baird. Herpetologica 6:139-140.

Longcore, J. R., J. E. Longcore, A. P. Pessier, and W. A. Halteman. 2007. Chytridiomycosis widespread in anurans of northeastern United States. Journal of Wildlife Management 71:435-444.

Mann, R. M., and J. R. Bidwell. 1999. The toxicity of glyphosate and several glyphosate formulations to four species of southwestern Australian frogs. Archives of Environmental Contamination and Toxicology 36:193-199.

Marco, A., and A. R. Blaustein. 1999. The effects of nitrite on behavior and metamorphosis in Cascades frogs (*Rana cascadae*). Environmental Toxicology and Chemistry 18:946-949.

McCallum, M.L. 1999. Acris crepitans (northern cricket frog) Death Feigning. Herpetological Review 30:90.

McCallum, M.L. 2010. Future climate change spells catstophe for Blanchard's cricket frog, *Acris blanchardi* (Amphibia: Anura: Hylidae). Acta Herpetologica 5(1):119-130.

McCallum, M.L. 2011. Orientation and directional escape by Blanchard's cricket frog, *Acris blanchardi,* in response to a human predator. Acta Herpetologica 6:161-168.

McCallum, M.L., C. Brooks, R. Mason and S.E. Trauth. 2011. Growth, reproduction and life span in Blanchard's Cricket Frog (*Acris blanchardi*) with notes on the growth of the Northern Cricket Frog (*Acris crepitans*). Herpetology Notes 4:25-35.

McCallum, M. L., and S. E. Trauth. 2003a. A forty-three year museum study of northern cricket frog (*Acris crepitans*) abnormalities in Arkansas: upward trends and distributions. Journal of Wildlife Diseases 39:522-528.

McCallum, M. L., and S. E. Trauth. 2003b. *Acris crepitans* (northern cricket frog) communal hibernaculum. Herpetological Review 34:288.

McCallum, M.L. and S.E. Trauth. 2004. Blanchard's cricket frog in Nebraska and South Dakota. Prarie Naturalist 36:129-135.

McCallum, M. L., and S. E. Trauth. 2006. An evaluation of the subspecies *Acris crepitans blanchardi* (Anura, Hylidae). Zootaxa 1104:1-21.

McCallum, M. L., and S. E. Trauth. 2007. Physiological trade-offs between immunity and reproduction in the northern cricket frog (*Acris crepitans*). Herpetologica 63:269-274.

McCallum, M.L., B.A.Wheeler, and S.E. Trauth. 2001. Acris crepitans (northern cricket frog) attempted cannibalism. Herpetological Review 32:99-100.

McKean K. and G. Kenney. 2012. Northern cricket frog research summary 2009-2010. NYSDEC report. 20pp.

Micancin, J. P. 2008. Acoustic variation and species discrimination in southeastern sibling species, the cricket frogs *Acris creiptans* and *Acris gryllus*. Dissertation, University of North Carolina, Chapel Hill, North Carolina, USA.

Micancin, J. P., and J. T. Mette. 2009. Acoustic and morphological identification of the sympatric cricket frogs *Acris creptians* and *A. gryllus*, and the disappearance of *A. gryllus* near the edge of its range. Zootaxa 2076:1-36.

Micancin, J.P., A. Toth, R. Anderson, and J.T. Mette. 2012. Sympatry and Syntopy of the cricket frogs *Acris crepitans* and *Acris gryllus* in southeastern Virginia, USA and decline of *A. gryllus* at the northern edge of its range. Herpetological Conservation and Biology 7:276-298.

Michigan Natural Features Inventory. 2007. Rare species explorer: *Acris crepitans blanchardi*: Blanchard's cricket frog. < http://mnfi.anr.msu.edu/explorer/species.cfm?id=10848>. Accessed 18 March 2010.

Mierzwa, K. S. 1998. Status of northeastern Illinois amphibians. Pages 115-124 *in* M. J. Lannoo, editor. Status and conservation of Midwestern amphibians. University of Iowa press, Iowa City, Iowa.

Milius, S. 1998. Fatal skin fungus found in U.S. frogs. Science News 154:7.

Minnesota Department of Natural Resources. 2010. Rare species guide: *Acris crepitans*: northern cricket frog. <http://www.dnr.state.mn.us/rsg/profile.html>. Accessed 18 March 2010.

Minton, S. A. 1998. Observations on Indiana amphibian populations: a forty-five year overview. Pages 217-220 *in* M. J. Lannoo, editor. Status and conservation of Midwestern amphibians. University of Iowa press, Iowa City, Iowa.

Mossman, M. J., L. M. Hartman, R. Hay, J. R. Sauer, and B. J. Dhuey. 1998. Monitoring long-term trends in Wisconsin frog and toad populations. Pages 169-198 *in* M. J. Lannoo, editor. Status and conservation of Midwestern amphibians. University of Iowa press, Iowa City, Iowa.

National Amphibian Atlas. 2009. Northern cricket frog (Acris crepitans) species map. http://igsaceeswb00.er.usgs.gov:8080/mapserver/naa/. Accessed 10 March 2010.

New York Natural Heritage Program. 2010. Animal Guide of Northern Cricket Frog. http://www.acris.nynhp.org/guide.php?id=6706 Accessed 20 July 2010.

New York State Department of Environmental Conservation (NYSDEC). 1981. Programmatic environmental impact statement on aquatic vegetation control program of the Department of Environmental Conservation Division of Lands and Forests.

New York State Federation of Lake Associations (NYSFOLA). 2009. Diet for a small lake: the expanded guide to New York State lake and watershed management. Second edition. New York State Federation of Lake Associations, Inc.

Nevo, E. 1973. Adaptive variation in size of cricket frogs. Ecology 54:1271-1281.

North American Amphibian Monitoring Program. 2009. Species detection map. <http://www.pwrc.usgs.gov/naamp/index.cfm?fuseaction=app.routeSpeciesDetectionMap>. Accessed 10 March 2010.

Nyman, S. 1986. Mass mortality in larval *Rana sylvatica* attributable to the bacterium, *Aeromonas hydrophila*. Journal of Herpetology 20:196-201.

Ohio Frog and Toad Calling Survey. 2005 March 26. Blanchard's cricket frog (*Acris crepitans blanchardi*). < http://www.ohioamphibians.com/frogs/cricket_frog.html>. Accessed 18 March 2010.

Oldham, M. J. 2003. Conservation status of Ontario amphibians. Natural Heritage Information Centre, Ontario Ministry of Natural Resources. Peterborough, Ontario, Canada.

O'Neill. 2001. Determination of a terrestrial buffer zone for conservation of the cricket frog *Acris crepitans*. Thesis, Illionois State University, Normal, Illinois, USA.

Orton, G. L. 1952. Key to the genera of tadpoles in the United States and Canada. American Midland Naturalist 47:382-395.

Ozard, J.W. 1991. Memoradum: Ecological Zoning of New York. File copy. 2 pp.

Paloski, R. A., R. Hay, and T. L. E. Bergeson. 2010. Northern cricket frog species guidance. PUB-ER-666. Bureau of Endangered Resources, Wisconsin Department of Natural Resources, Madison, Wisconsin.

Pendall, R. 2003. Sprawl without growth: the upstate paradox. The Brookings Institution, Washington, D. C., USA.

Pennsylvania Fish and Boat Commission. 2010. <http://www.fish.state.pa.us/rulemakings/215nprp.pdf>. Accessed 3 March 2010.

Perrill, S. A., and M. Magier. 1988. Male mating behavior in *Acris crepitans*. Copeia 1988:245-248.

Perrill, S. A., and W. J. Shepherd. 1989. Spatial distribution and male-male communication in the northern cricket frog, *Acris crepitans blanchardi*. Journal of Herpetology 23:237-243.

Pessier, A. P., D. K. Nichols, J. E. Longcore, and M. S. Fuller. 1999. Cutaneous chytridiomycosis in poison dart frogs (*Dendrobates* spp.) and White's tree frogs (*Litoria caerulea*). Journal of Veterinary Diagnostic Investigation 11:194-199.

Pilliod, D. S., and C. R. Peterson. 2001. Local and landscape effects of introduced trout on amphibians in historically fishless watersheds. Ecosystems 4:322-333.

Pyburn, W. F. 1958. Size and movements of a local population of cricket frogs (*Acris creptians*). Texas Journal of Science 10:325-342.

Pyburn, W. F. 1961. The inheritance and distribution of vertebral stripe color in the cricket frog. Pages 235-261 *in* W. F. Blair, editor. Vertebrate Speciation. University of Texas Press, Austin.

Reeder, A. L., G. L. Foley, D. K. Nichols, L. G. Hansen, B. Wikoff, S. Faeh, J. Eisold, M. B. Wheeler, R. Warner, J. E. Murphy, and V. R. Beasley. 1998. Forms and prevalence of intersexuality and effects of environmental contaminants on sexuality in cricket frogs (*Acris crepitans*). Environmental Health Perspectives 106:261-266.

Reeder, A. L., M. O. Ruiz, A. Pessier, L. E. Brown, J. M. Levengood, C. A. Phillips, M. B. Wheeler, R. E. Warner, and V. R. Beasley. 2005. Intersexuality and the cricket frog decline: historic and geographic trends. Environmental Health Perspectives 113:261-265.

Relyea, R. A. 2005. The lethal impacts of Roundup and predatory stress on 6 species of North American tadpoles. Archives of Environmental Toxicology 48:351-357.

Relyea, R. A. 2009. A cocktail of contaminants: how mixtures of pesticides at low concentrations affect aquatic communities. Oecologia 159:363-376.

Rose, F. L., T. R. Simpson, M. R. J. Forstner, D. J. McHenry, and J. Williams. 2006. Taxonomic status of *A. gryllus paludicola*: in search of the pink frog. Journal of Herpetology 40:428-434.

Rosenzweig, C., Solecki, W., DeGaetano, A., et al. *Responding to Climate Change in New York State: The ClimAID Integrated Assessment for Effective Climate Change Adaptation in New York State*, final report for the New York State Energy Research and Development Authority, 2011.

Rygg, B. 1985. Effect of sediment copper on benthic fauna. Marine Ecology Progress Series 25:83-89.

Sessions, S. K., and S. B. Ruth. 1990. Explanation for naturally occurring supernumary limbs in amphibians. Journal of Experimental Zoology 254:38-47.

Siemering, G. S., J. D. Hayworth, and B. K. Greenfield. 2008. Assessment of potential aquatic herbicide impacts to California aquatic ecosystems. Archives of Environmental Contamination and Toxicology 55:415-431.

Skelly, D. K., E. E. Werner, and S. A. Cortwright. 1999. Long-term distributional dynamics of a Michigan amphibian assemblage. Ecology 80:2326-2337.

Smith, P. W. 1961. The amphibians and reptiles of Illinois. Illinois Natural History Survey Bulletin 28 (1), 298 pages.

Smith, C. L. 1985. The inland fishes of New York State. NewYork State Department of Environmental Conservation. Albany, New York, USA.

Steiner, S.L., R. Lehtinen, D. Fraga. 2007. Is Chytridiomycosis (Batrachochytrium dendrobatidis) present in declining population of Blanchard's cricket frog (Acris crepitans blanchardi)?. Ohio Journal of Science. 107(1):A-8.

Stuart, S. N., J. S. Chanson, N. A. Cox, B. E. Young, A. S. L. Rodrigues, D. L. Fischman, and R. W. Waller. 2004. Status and trends of amphibian declines and extinctions worldwide. Science 306:1783-1786.

Sutherland, D. 2005. Parasites of North American frogs. Pages 109-123 *in* M. Lannoo, editor. Amphibian declines: the conservation status of United States species. University of California press, Berkeley and Los Angeles, California.

Swanson, D.L. and S.L. Burdick. 2010. Overwintering physiology and hibernacula microclimates of Blanchard's Cricket Frogs at their northwestern range boundary. Copeia 2010(2):247-253.

Tatum, V. L. 2004. Toxicity, transport, and fate of forest herbicides. Wildlife Society Bulletin 32:1042-1048.

Terhivuo, J. 1988. Phenology of spawning for the common frog (*Rana temporaria* L.) in Finland from 1846 to 1986. Annales Zoologici Fennici 25:165-175.

Trumbo, J. 2005. An assessment of the hazard of a mixture of the herbicide Rodeo and the non-ionic surfactant R-11 to aquatic invertebrates and larval amphibians. California Fish and Game 91:38-46.

U.S. Census Bureau. 2009. New York State and county quickfacts. <http://quickfacts.census.gov/qfd/states/36000.html>. Accessed 20 February 2010.

U.S. Fish and Wildlife Service, National Oceanic and Atmospheric Administration, and the New York State Department of Environmental Conservation. 2013. The national fish, wildlife, and plants climate adaptation strategy. 112pp.

Van Gorp, C. D. 2001. Changes in the distribution of *Acris crepitans blanchardi*, with studies of nesting microhabitat and the possible impact of ultraviolet-B radiation. Thesis, Drake University, Des Moines, Iowa, USA.

Wake, D. B. 1991. Declining amphibian populations. Science 253:860.

Walvoord, M. E. 2003. Cricket frogs maintain hydration and temperature near levels allowing maximum jump performance. Physiological and Biochemical Zoology 76:825-835.

West Virginia Department of Natural Resources: Wildlife Resources. 2003. Rare, threatened, and endangered species in West Virginia. <http://www.wvdnr.gov/ Wildlife/ RareSpecList.shtm>. Accessed 18 March 2010.

Westerveld, J. 2012. Tiny caller, the northern cricket frog. The New York State Conservationist. 2012(Feb): pp 22-24.

Wojtaszek, B.F., T.M. Buscarini, D.T. Chartrand, G.R. Stephenson, and D.G. Thompson. 2005. Effect of Release Herbicide on mortality, avoidance response, and growth of amphibian larvae in two forest wetlands. Environmental Toxicology and Chemistry 24(10):2533-2544.

Wojtaszek, B. F., B. Staznik, D. T. Chartrand, G. R. Stephenson, and D. G. Thompson. 2004. Effects of Vision herbicide on mortality, avoidance response, and growth of amphibian larvae in two forest wetlands. Environmental Toxicology and Chemistry 23:832-842.

Wright, A. H., and A. A. Wright. 1949. Handbook of frogs and toads. Cornell University Press, Ithaca, New York, USA.

Wyman, R. L., and D. S. Hawksley-Lescault. 1987. Soil acidity affects distribution, behavior, and physiology of the salamander *Plethodon cinereus*. Ecology 68:1819-1827.

Zaga, A., E. E. Little, C. F. Rebeni, and M. R. Ellersieck. 1998. Photoenhanced toxicity of a carbamate insecticide to early life stage anuran amphibians. Environmental Toxicity and Chemistry 17:2543-2553.

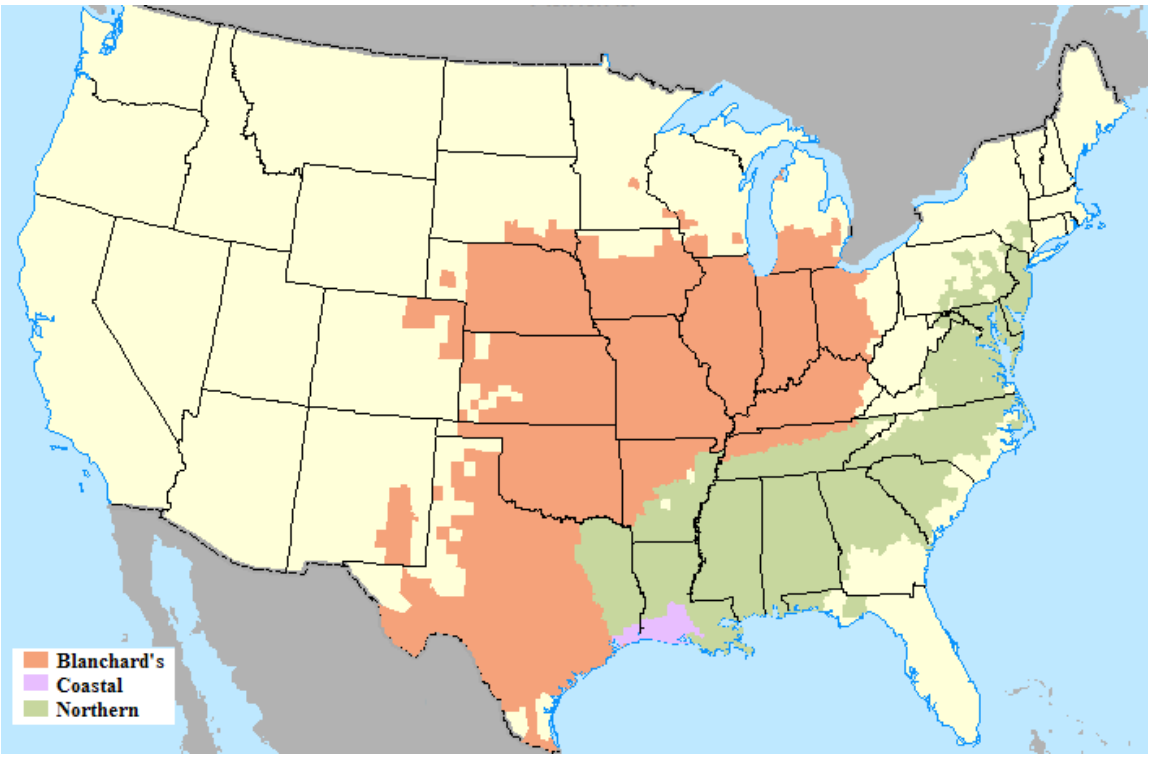


Figure 1. **The range of northern cricket frogs (*Acris crepitans*) in the United States, including the Blanchard's (*A. c. blanchardi*), coastal (*A. c. paludicola*), and northern (*A. c. crepitans*) subspecies. This map was constructed based on range maps from Conant and Collins (1998), and the websites of state wildlife agencies, the National Amphibian Atlas (2009), the North American Amphibian Monitoring Program (2009), and the Center for Reptile and Amphibian Conservation and Management (2010). Note: The status of some populations is uncertain, and therefore some locations may represent historic rather than extant populations.**

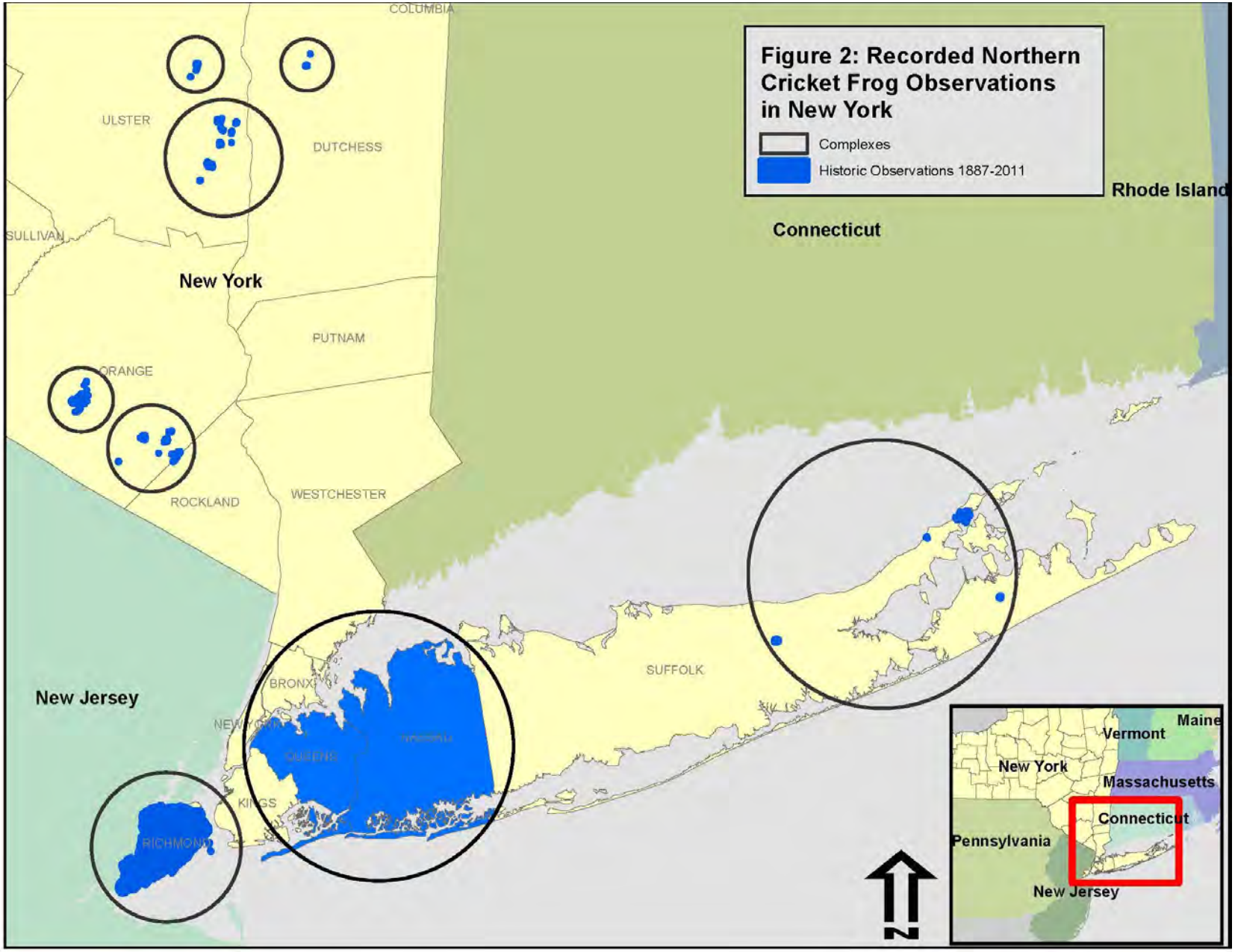


Figure 2: Recorded Northern Cricket Frog Observations in New York
Complexes
Historic Observations 1887-2011
COLUMBIA
ULSTER
DUTCHESS
SULLIVAN
New York
PUTNAM
ORANGE
ROCKLAND
WESTCHESTER
Connecticut
Rhode Island
New Jersey
BRONX
QUEENS
KINGS
RICHMOND
SUFFOLK
Maine
Vermont
New York
Massachusetts
Connecticut
Pennsylvania
New Jersey
N

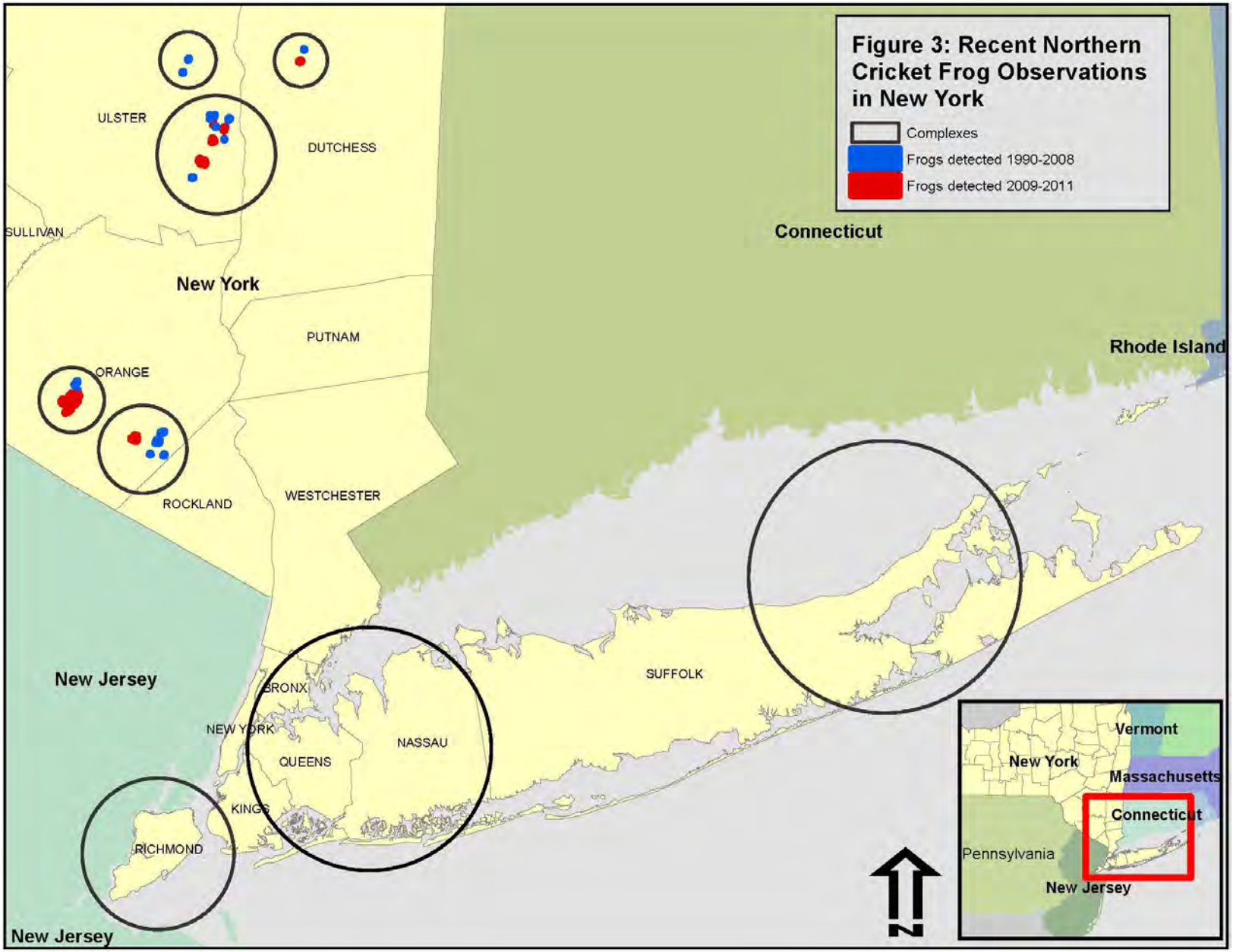


Figure 3: Recent Northern Cricket Frog Observations in New York
Complexes
Frogs detected 1990-2008
Frogs detected 2009-2011
ULSTER
DUTCHESS
SULLIVAN
New York
PUTNAM
ORANGE
ROCKLAND
WESTCHESTER
Connecticut
Rhode Island
New Jersey
BRONX
NEW YORK
QUEENS
KINGS
RICHMOND
NASSAU
SUFFOLK
New Jersey
Vermont
New York
Massachusetts
Connecticut
Pennsylvania
New Jersey
N

Figure 4. Comparison images of the town of Southold, one of the areas that northern cricket frogs once occupied but have since been extirpated. The image on the left is an aerial photograph from 1928, courtesy of Suffolk County Planning Dept. The image on the right is an early spring 2011 photo courtesy of Google Earth.

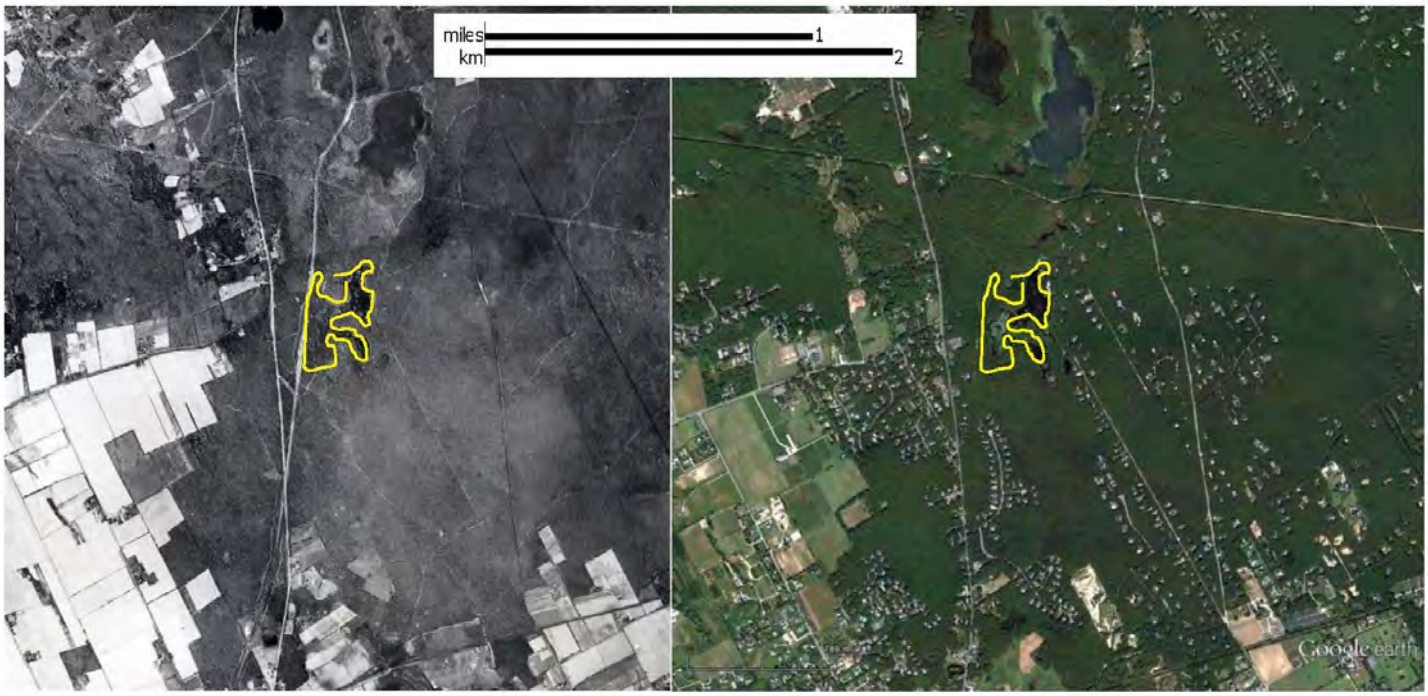


Figure 5. Comparison images of Crooked Pond, one of the areas that northern cricket frogs once occupied in Long Island but have since been extirpated. The image on the left is an aerial photograph from 1928, courtesy of Suffolk County Planning Dept. The image on the right is a summer 2012 photo courtesy of Google Earth.

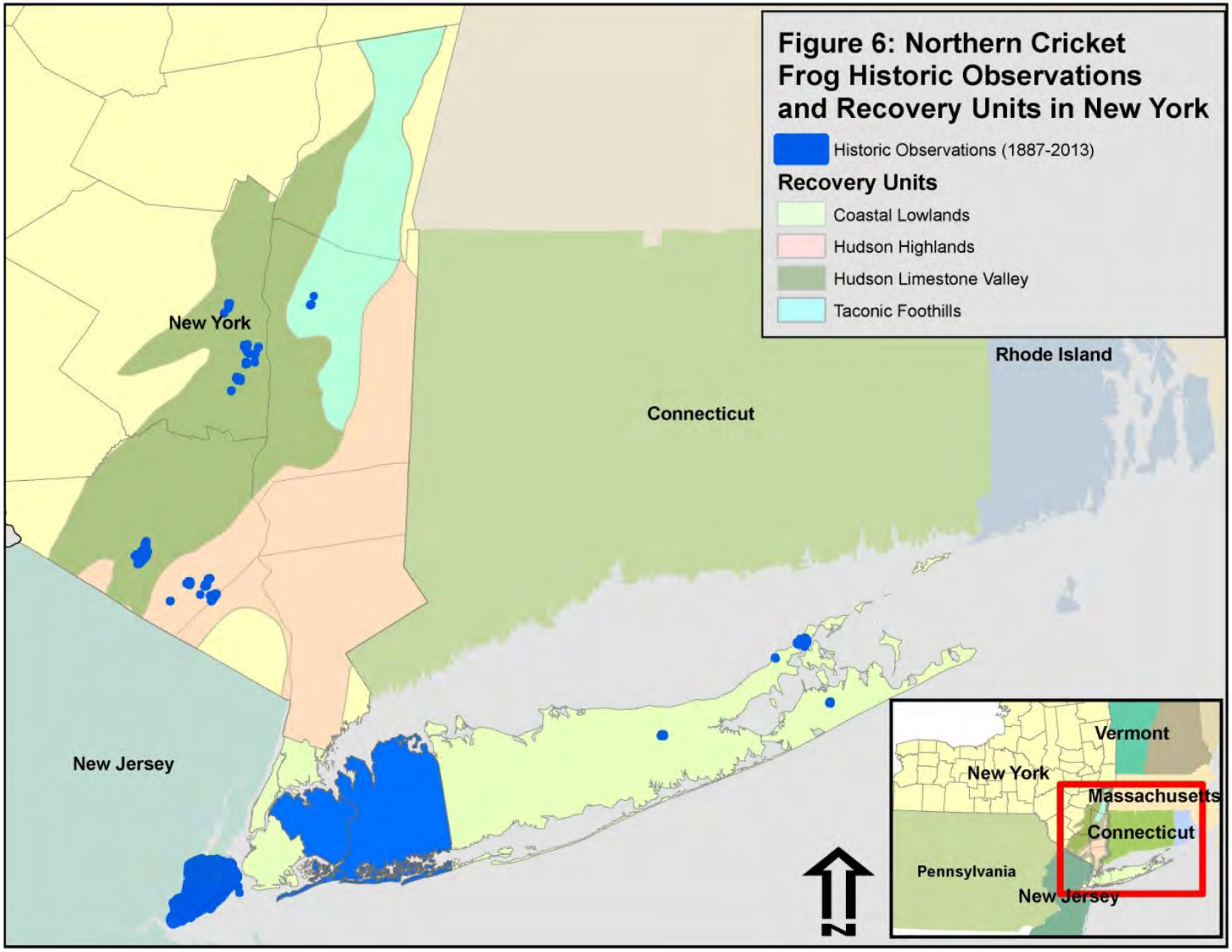


Figure 6: Northern Cricket Frog Historic Observations and Recovery Units in New York
Historic Observations (1887-2013)
Recovery Units
Coastal Lowlands
Hudson Highlands
Hudson Limestone Valley
Taconic Foothills
New York
Connecticut
Rhode Island
New Jersey
Vermont
New York
Massachusetts
Connecticut
Pennsylvania
New Jersey
N

APPENDIX I

Northern Cricket Frog Project Screening Process

Northern Cricket Frog Project Screening Process

Protection Status

New York: Endangered
Federal: Not Listed

1. Are there any known occurences of Northern Cricket Frog within 1/2 mile of the proposed project site (i.e. NYNHP element occurrence)?

- **No** → **A**
- **Yes** →

2. Does the intervening landuse between the proposed project site and all known NCF breeding populations include significant dispersal barriers (e.g. primary roads [non-elevated, without underpasses, overpasses or culverts], major rivers, or urban areas) that would prevent passage of frogs?

- **No or Unknown** →

3. Is the proposed project site within 1,500 feet of a known NCF breeding population (i.e. NYNHP element occurrence)?

- **No** →

4. Will the proposed project include any actions that may affect surface hydrology or water quality *OR* require any of the following?

- Issuance of a DEC Freshwater Wetlands (Article 24) permit
- Issuance of a Stream Disturbance (Article 15) permit
- Issuance of a SPDES (Article 17) permit

- **No** → **A**
- **Yes or Unknown** →

5. Will any of these actions impact off-site habitats known to contain NCF breeding populations?

- **No** →

6. Are there potential aquatic breeding habitats on the project site?

- **No** → **A**
- **Yes** → **B**

- **Yes or Unknown** → **C**

- **Yes or Unknown** →

4. Does the proposed project include physical alteration of land or disturbances such as...?

- Residential or commercial development
- Construction of roads or parking lots
- Construction of cellular towers
- Changes in agricultural practices
- Excavation and backfill
- Vegetation management (e.g. silviculture, herbicide application)
- Placement of permanent barriers such as fences or retaining walls
- Blasting, mineral extraction, or oil/natural gas drilling and refining
- Introduction of non-native fish species
- Alteration of wetland habitats (e.g. draining, filling, ditching)
- Alteration of surface hydrology (e.g. stream diversion, construction of impoundments)
- Alteration of aquatic vegetation (e.g. herbicide application, grass carp stocking)
- Change in water quality (e.g. chemical or fertilizer application, heavy grazing, stormwater runoff)

- **No** → **A**
- **Yes** →

5. Do any of these actions occur (in whole or in part) within 300 feet of a known NCF breeding population?

- **No** →

6. Is the proposed project limited to small-scale (<1 acre) or impermanent upland disturbances ONLY (e.g. cell tower construction, timber harvest, construction within the disturbance footprint of existing structures)?

- **No or Unknown** → **C**
- **Yes** → **D**

- **Yes** → **C**

- **Yes** →

3. Will the proposed project include any actions that may affect the surface hydrology (e.g. stream diversion, construction of impoundments) or water quality (e.g. pesticide application, use of fertilizers, changes in agricultural practices, stormwater runoff) of any off-site habitats that are known to include NCF breeding populations?

- **A** → **A**
- **C** → **C**

A **The proposed project is not likely to have a significant impact on the NCF population; no further review regarding NCF at this site is necessary at this time.**

B **Project is potentially within dispersal corrdior of NCF. An auditory sampling survey may be required to determine if NCF are present. If NCF are detected, additional assessment may be required.**

C **Potential impacts to NCF must be assessed. The project design should avoid alteration of NCF habitats and incorporate appropriate mitigation measures to prevent impacts to the frogs that would constitute a "take" under ECL Section 11-0535. If potential impacts cannot be eliminated, surveys must be conducted to 1) identify suitable NCF summer and over-wintering habitats, 2) determine the presence and probable absence of NCF within the project site, 3) assess movement of NCF between breeding and over-wintering habitats. Results of these surveys will determine what additional information and/or mitigation may be required.**

D **Disturbance to upland habitats should only be conducted during the acceptable work period (June 1st through August 15th) when NCF are normally at their breeding locations.**

Revised 8/23/2010; G. Kenney Revised 12/29/2008; S. Joule

APPENDIX II

Northern cricket frog calling survey protocols

Call Survey Protocol

1. All surveys should be conducted between May 20 - July 10, with at least one survey performed in June and each survey separated by seven (7) or more days.

2. Surveys should begin no earlier than one half (1/2) hour after sunset and end no later than midnight.

3. Ambient air temperature should be at least 60° F.

4. Wind speed should be less than thirteen (13) mph.

5. After reaching a sampling point, the surveyor should wait at least one minute before beginning the survey and each sampling point should then be surveyed for at least ten (10) minutes.

6. At each sampling point the following information should be recorded:
   - Survey site name (e.g. project name) and location (county, town, village, Lat - Lon coordinates)
   - Survey date
   - Time at the start of the survey
   - Air temperature at the start of the survey
   - Water temperature at the end of the survey
   - Wind force at the start of the survey (Beaufort scale)
   - Cloud cover at the start of the survey (%)
   - Precipitation (none, mist, drizzle, light rain, heavy rain)
   - Noise level using the following categories: (Low - no affect on survey; Moderate – somewhat affecting ability to hear calling frogs; High – significantly affecting ability to hear calling frogs)

7. At each sampling point the following data should be collected:
   - Arial extent of suitable habitat (acres)
   - Habitat description
   - Number of individual frogs heard calling by species, using the following numerical categories: 0, 1, 2, 3, 4, 5, 6–10, and > 10
   - Number of northern cricket frogs observed

Beaufort Wind Codes	
0	Calm (<1mph) Smoke rises vertically
1	Light Air (1-3 mph) smoke drifts, weather vane inactive
2	Light Breeze (4-7 mph) leaves rustle, can feel wind on face
3	Gentle Breeze (8-12 mph) leaves and twigs move around, small flags extend
4*	Moderate Breeze (13-18 mph) moves thin branches, raises loose papers
5*	Fresh Breeze (19 mph or greater) small trees begin to sway

- Do not conduct survey at Level 4 or Level 5

Revised 2/28/2009; S. Joule

APPENDIX III

Northern cricket frog (*Acris crepitans*) population viability analysis

Prepared by: Jason Martin (Hudson River Estuary Program, Cornell University, New York State Department of Environmental Conservation)

Northern cricket frog (*Acris crepitans*) population viability analysis

Prepared by: Jason Martin (Hudson River Estuary Program, Cornell University, New York State Department of Environmental Conservation)

Introduction

Northern cricket frogs (*Acris crepitans*; hereafter, NCF) are distributed throughout most of the eastern United States; however, population declines and local extirpations have occurred in many areas in recent decades, especially in the northern and western extents of this range (Conant and Collins 1998, McCallum and Trauth 2003, Gray and Brown 2005, Reeder et al. 2005). In New York, the distribution of NCF historically was restricted to the lower Hudson Valley, Staten Island, and Long Island (Gibbs et al. 2005) and the species has been extirpated from many locations. As of 1999, NCF were known to occupy at least 15 distinct water bodies in New York (NY Natural Heritage Program, unpublished data). NCF were found in six of these locations during surveys conducted by NYSDEC personnel during the 2009 and 2010 breeding seasons and the status of NCF populations in four other locations currently is unclear. It should be noted that the intensity of the 2009 and 2010 surveys was variable. NCF is classified as endangered in New York State, although specific factors leading to decline are not known. Potential drivers of population declines include habitat loss and degradation, habitat fragmentation, impacts of chemical pollutants, climate change, pathogens, acidic precipitation, ultraviolet radiation, and non-native species introduction (Leftwich and Lilly 1992, Fellers and Drost 1993, Greenwell et al. 1996, Blaustein et al. 1998, Leja 1998, Skelly et al. 1999, Lehtinen 2002, Gray and Brown 2005, Johnson and Lunde 2005, Reeder et al. 2005).

Population viability analyses (PVA's) are species-specific risk assessments that predict the likelihood of a population or metapopulation becoming extinct within a defined timeframe given the natural history of the species and potential impacting factors, such as hunting pressure or stochastic environmental disasters. They have previously provided invaluable information that has aided in the recovery of many declining species (e.g., Lacy et al. 1989, Seal et al. 1990). *Vortex* is a software program frequently used for conducting population viability analyses (Lacy et al. 2009). It utilizes a Monte Carlo simulation approach by modeling probability of population survival using repeated iterations based on randomly generated values that follow specified distributions as well as constant deterministic variables. *Vortex* also is capable of incorporating demographic, environmental, and genetic stochastic events into population viability simulations (Lacy et al. 2009). PVA's are not intended to provide definitive population projections because of the inherently random nature of the modeling approach as well as the uncertainty that typically is involved in defining the demographic parameters used as model inputs. Rather, they provide a probabilistic prediction of population survival over time. Additionally, they are extremely useful tools for identifying important natural history data gaps that may exist for a given species and for prioritizing research needs and management actions.

Our population viability analysis for NCF was conducted using *Vortex 9.99* (Lacy et al. 2009) and was modeled after a PVA of the Chiricahua Leopard Frog (*Rana chiricahuensis*; U.S. Fish

and Wildlife Service 2007). Specifically, we were interested in examining the following questions:

- What is the extent of our understanding of the population biology of NCF and what data gaps exist?
- What impact does population size have on long-term stability of NCF populations?
- How is the stability of a small population of NCF affected when it is linked via dispersal to secondary populations of various sizes?
- How would a metapopulation of NCF function given a range of biologically likely subpopulation sizes and dispersal rates?

Baseline population model

Breeding system and annual activity: We assumed that NCF have a polygynous mating system. In New York, adult females breed once per year, with peak activity occurring in June and July (NYS Herp Atlas, unpublished data). Frogs are active until October or November at which time they enter hibernation (Gray 1971). Our *Vortex* time-step equaled one year (244 active days, 121 hibernation days).

Age of first reproduction and reproductive senescence: For the purpose of these models, we defined reproduction as the successful production of metamorph recruits into the adult population. NCF's begin reproducing during the spring following their first hibernation period (Veldman 1997, Bayne 2004). Individuals of this species have an average life expectancy of less than one year (Burkett 1984, O'Neill 2001, Gray and Brown 2005), although adults occasionally survive to a second breeding season (Gray 1983). Therefore, we used two years as the age of reproductive senescence.

Offspring production: Density dependent reproduction occurs when reproductive output of a population is limited at high densities due to insufficient resources (e.g., food, available breeding locations). We assumed that NCF exhibit density dependent reproduction. Because information pertaining to the impact of resource limitation on reproductive output of this species is not available, we conservatively assumed that 100% of females in NCF populations breed at low densities [P(0)] and 80% breed when populations are near or at carrying capacity [P(K)]. Density-independent factors, such as fluctuation in mean annual temperature, also bound the potential size of populations. We modeled environmental variation in reproductive success by specifying a standard deviation of 10 for the proportion of adult females that successfully produce metamorphs. No data is available on which to base this parameter, however we assume that this variation would be relatively high because of the variety of potential environmental factors that may directly or indirectly impact reproductive success (e.g., annual temperature fluctuations, drought). This value also is similar to that used in a population viability analysis of cricket frogs in Illinois (Veldman 1997). We further assumed that 100% of male frogs are potential breeders at any population size.

Female NCF's lay 200-400 eggs per year (Burkett 1984, Van Gorp 2001, Dickson 2002, Gray and Brown 2005). Survivorship from egg to metamorph is unknown for this species, so we used wood frog (4%; Carey and Bryant 1995), spotted frog (4.4%; Carey and Bryant 1995), and dusky gopher frog (5.4%; Richter et al. 2003) as surrogate species. Using a 5% survivorship rate from

egg to metamorph and an average of 300 eggs produced per female, we calculated a mean value of 15 metamorphs produced per female cricket frog per year. We set the standard deviation for this estimate at a relatively small value of 2. We estimated that each female would produce a maximum of 40 metamorphs annually (10% of 400 eggs). Based on several other studies (Pyburn 1958, Burkett 1984, Veldman 1997, Dickson 2002), we assumed that the sex ratio of NCF metamorphs is 50:50.

Inbreeding depression: Inbreeding depression is defined as a reduction in the overall reproductive fitness of a population resulting from the interbreeding of closely related individuals and subsequent increased expression of recessive deleterious genetic traits. The expression of such traits often leads to reduced reproductive output or mortality of individuals. In large populations recessive lethal genes typically are repressed, however as populations shrink and/or become isolated from other populations deleterious genes are increasingly expressed. As a result, these populations may have a high proportion of individuals that are no longer optimally adapted to survive in their given range of habitat conditions, will have lower reproductive success compared to more fit populations, and may ultimately become extirpated. Data pertaining to inbreeding depression in NCF populations is not available, so we elected to initially use the default value provided in *Vortex* of 3.14 lethal equivalents, approximately 50% of which are expressed as lethal traits. These values are based on a survey of 40 captive populations of wildlife (Ralls et al. 1988).

Mortality: NCF's typically have life spans of ≤ 2 years, with a mortality rate during the first year well exceeding that during the second year (Burkett 1984, Veldman 1997, Bayne 2004). Based on the results of a mark-recapture study of cricket frogs in Illinois (Veldman 1997), we estimated mortality of cricket frogs in New York to be 65% during their first year and 10% during their second year.

Catastrophes: NCF's lack the freeze tolerant adaptations found in other species of frogs. Therefore, overwintering mortality may have a large impact on this species, especially in the northern extent of its range. However, there is much uncertainty concerning the magnitude of impact that this source of mortality may have. Burkett (1984) and Bayne (2004) determined that there may be an overwintering mortality rate of up to 95% in some populations, but Gray (1983) suggested that such severe annually observed population declines may instead be attributable to mass emigration during the fall and thus we chose to be more conservative in our estimation. We modeled overwintering mortality by incorporating an annually occurring catastrophe that lowered overall survival by 60% but had no impact on reproduction.

Initial population size and carrying capacity: Population densities of species are determined by many interconnected factors (e.g., habitat quantity and quality, predation pressure) and can vary widely among locations. Veldman (1997) estimated populations of cricket frogs to be less than 50 individuals in each of five small ponds and three sections of stream (no specific sizes were provided for these locations). Bayne (2004) estimated densities of 9-62 frogs/acre, while estimates of Pyburn (1958) and Dickinson (1993) were far less (<1 frog/acre). Gray (1983) and Burkett (1984) took a different approach to estimating density of cricket frog populations by approximated 0.25-10 frogs per meter of shoreline. Following the most conservative estimates of this later technique and given the range in sizes of water bodies in southeastern NY known to

harbor NCF's, we speculated that extant breeding populations in NY range from 500-5000 frogs. However, it is likely that smaller, undetected populations may exist as well. It must be emphasized that these estimates are not based on field data and should not be considered as accurate estimates of real population sizes. Given this caveat, as well as limitations in computing capacity, we decided to set the initial population size at 250 individuals.

Carrying capacity (K) refers to the maximum number of individuals that can be supported in a habitat patch given the limitations of natural resource availability. Carrying capacities typically fluctuate because of changes in habitat quality, therefore estimating K can be very difficult. For purposes of our modeling, we presumed that K would be 1.5 times the initial population size. This allowed for populations to fluctuate not just below, but also slightly above, the initial value following the production of offspring.

Table 1. Demographic input parameters for the baseline *Vortex* simulation model for NCF in southeastern New York.

Model input	Baseline value
Time-steps	100
Iterations	500
Breeding system	Polygynous
Age of first reproduction (♂/♀)	1/1
Maximum age of reproduction	2
Annual % adult females reproducing (SD)	100-[(100-80)*((N/K)^1)]*[N/(0+N)] (10)
% adult males in breeding pool	100
Maximum number of broods per year	1
Mean number of metamorphs per clutch (SD)	15 (2)
Maximum number of metamorphs per clutch	40
Sex ratio at birth	50:50
Number of lethal equivalents per individual	3.14
% annual mortality 0-1 year olds (SD)	65 (5)
% annual mortality 1+ year olds (SD)	10 (2)
Catastrophe	Overwinter mortality
Annual frequency of catastrophe (%)	100
Multiplicative effect of catastrophe on reproduction	1
Multiplicative effect of catastrophe on survival	0.4
Initial population size	250
Carrying capacity	375

Demographic sensitivity analysis

Several of the demographic parameters necessary for conducting population viability analyses for NCF's have a wide margin of uncertainty. We selected four parameters with the highest degree of uncertainty to conduct an analysis of the relative impact that variation in these

parameters would have on the overall model. We created eight models using biologically reasonable high and low estimates of each uncertain parameter (see below) while holding all other parameters at the initial values listed in Table 1. We then graphically compared population growth rates of these models to the growth rate yielded by the model using only the baseline parameter values (Fig. 1). The results of this analysis may not only be useful when interpreting model output, but also in prioritizing research and management actions that may have the highest beneficial impact for NCF conservation.

Lethal equivalents: While we felt that inbreeding depression likely has some impact on NCF population demographics, we were unable to locate any data pertaining specifically to inbreeding depression levels in this species. In addition to the *Vortex* default value of 3.14 lethal equivalents, we also chose to model the impact of lethal equivalent values of 1 and 10, based on Levins (1984) and Spielman et al. (2004) respectively, to represent biologically meaningful minimum and maximum values.

Mean brood size: Our initial value of mean brood size was based on a 5% survival rate of 300 eggs produced annually per female frog. However, estimates of egg production by NCF range from 200-400 (Burkett 1984, Van Gorp 2001, Dickson 2002, Gray and Brown 2005). To account for this wide variation in potential fecundity, we also modeled mean brood sizes of 10 (5% of 200) and 20 (5% of 400).

Overwinter mortality: Estimates of overwintering mortality vary widely among NCF studies. In addition to the 60% mortality rate that we incorporated into our baseline population model, we modeled a higher rate (80%) similar to that found in other studies (Gray 1983, Burkett 1984, Bayne 2004) and a lower mortality rate of 40%.

Summer mortality: Little data exists pertaining to age-specific survivorship of NCF's. We based our initial estimates (juvenile mortality = 65%, adult mortality = 10%) on those of Veldman (1997), however his sample size was small. To examine relative impact of juvenile and adult mortality on overall population survivorship, we modeled 10% increases in mortality of juveniles and adults while concurrently holding the mortality rate of the other life stage at the initial value.

Initial population size analysis

This analysis examined the impact of population size on long-term population stability. These data may be useful for determining appropriate targets for population sizes to minimize risk of extirpation. Small populations may be more susceptible to extirpation than larger populations because they can be more vulnerable to the effects of inbreeding depression and stochastic environmental fluctuations. We compared our baseline model to models with initial population sizes of 50, 100, 500, and 1000. In addition to population growth rate, we also compared genetic heterozygosity and likelihood of population survival over 100 years among these models.

We incorporated a second catastrophe into these and all subsequent models to simulate severe winters. We felt that this more realistically modeled the impact of overwintering mortality on long-term viability of NCF populations. By identifying the total number of days annually with

temperatures below 0°C over the past 60 years (National Climate Data Center, NOAA; West Point, NY weather station), we determined that severe winters (i.e., those with >55 days below freezing) occur approximately every 10 years. We speculate that NCF populations experience particularly high rates of overwintering mortality during these extreme years. Overall in our models, the "severe winter" catastrophe had a 10% chance of annual occurrence which lowered overall survival an additional 50%.

Metapopulation analysis

The purpose of this analysis was to 1) examine the potential for a small population, which would not be viable existing in an isolated state, to be supported by a second small population, a medium-sized population, and a large population, 2) compare long-term stability of a single medium-sized population vs. an equally-sized metapopulation consisting five small subpopulations, and 3) compare long-term stability of four metapopulations with varying subpopulation sizes: 4 small; 2 small and 2 medium; 3 small and 1 large; 1 small, 2 medium, and 1 large). Specific parameters included in these models are as follows:

Subpopulation size: We classified subpopulations as either small (100 frogs), medium (500 frogs), or large (1000 frogs). These sizes coincide with those used throughout our population simulation, and to a certain extent were limited by computing capacity. Carrying capacity values were identical to those previously presented.

Dispersal: In our models, we assumed both males and females disperse equally. All individuals were capable of dispersing in their first year and ceased dispersing after their second year, which was equivalent to the maximum expected age of NCF as defined elsewhere in our population viability simulations. We further assumed a 90% survival rate of dispersing individuals, although no data exists on which to base this estimate. Our dispersal models were not spatially explicit, therefore all subpopulations were assumed to be equally within the dispersing capability of all individuals of all other subpopulations. In all metapopulation simulations, we modeled 3 rates of dispersal (2%, 10%, and 25%) indicating the proportion of individuals emigrating from each subpopulation. These values were representative of the range of dispersal rates found in other studies of NCF and other frog species (Berven and Grudzien 1990, Veldman 1997, Peter 2001, Pilliod et al. 2002). When >2 subpopulations were modeled, we assumed that surviving emigrants from each subpopulation were evenly divided among all other subpopulations within the metapopulation. For example, in a metapopulation with 4 subpopulations and a dispersal rate of 10%, 3.3% of each subpopulation dispersed to each other subpopulation.

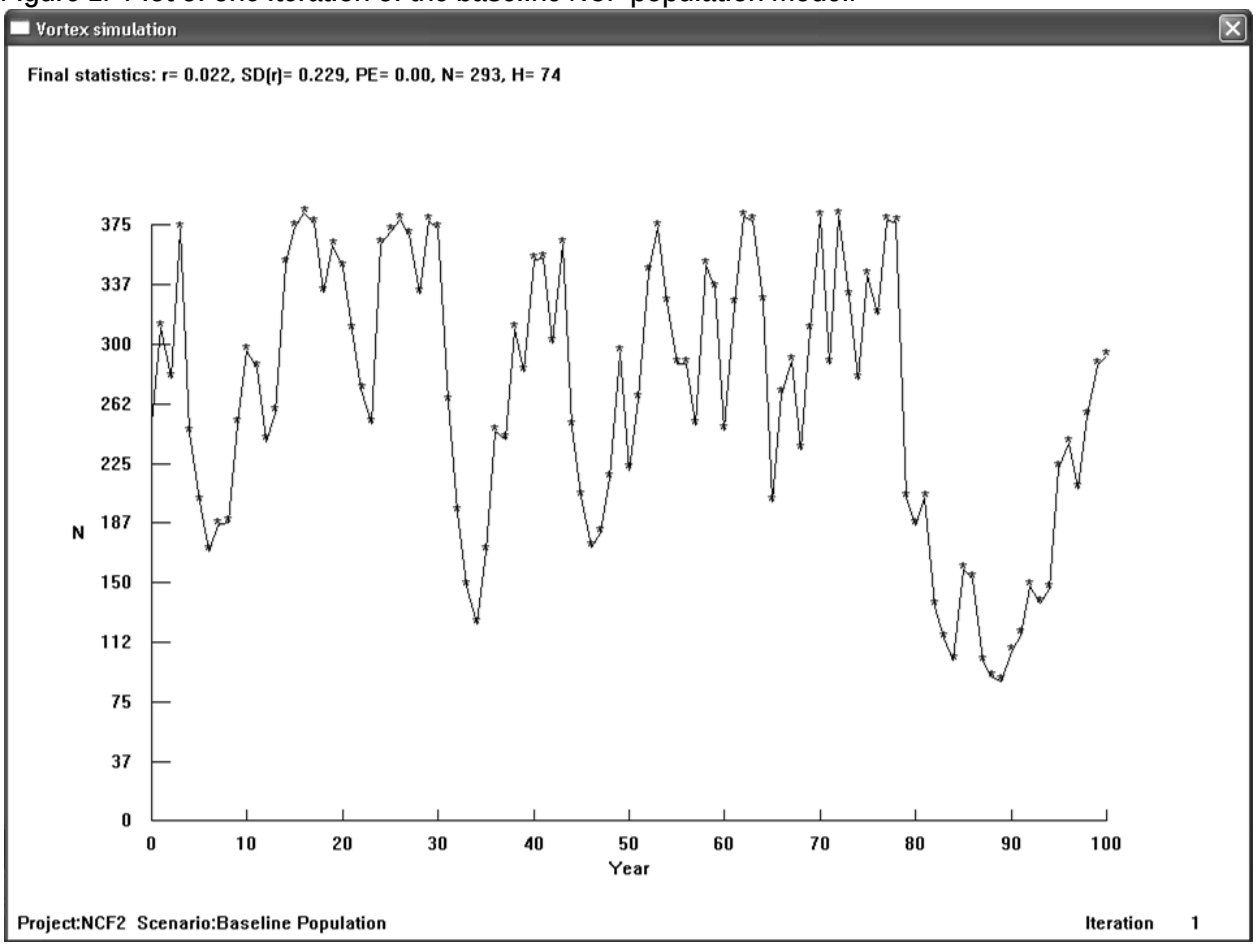
Results and conclusions of population viability modeling

Baseline population model

Our baseline model yielded a stable population over the span of 100 years. There was a slightly positive stochastic growth rate (r_s=0.054, SD=0.203) indicating the potential for the model population to fill unoccupied niche space or to expand if the amount of available habitat were increased. Additionally, there was a 0% risk of extinction over 100 years. However, observed heterozygosity declined nearly 21% (from 1.000 to 0.793) signifying that a reduction in

population abundance, and possibly extirpation, could occur over a longer time span. The model also produced extreme fluctuations in abundance estimates throughout the timeframe of the model, with population size ranging from approximately 15 individuals to 375. This likely was due to the stochastic nature of *Vortex* modeling. Examples of these fluctuations are shown in the single model iteration depicted in figure 1.

Figure 1. Plot of one iteration of the baseline NCF population model.



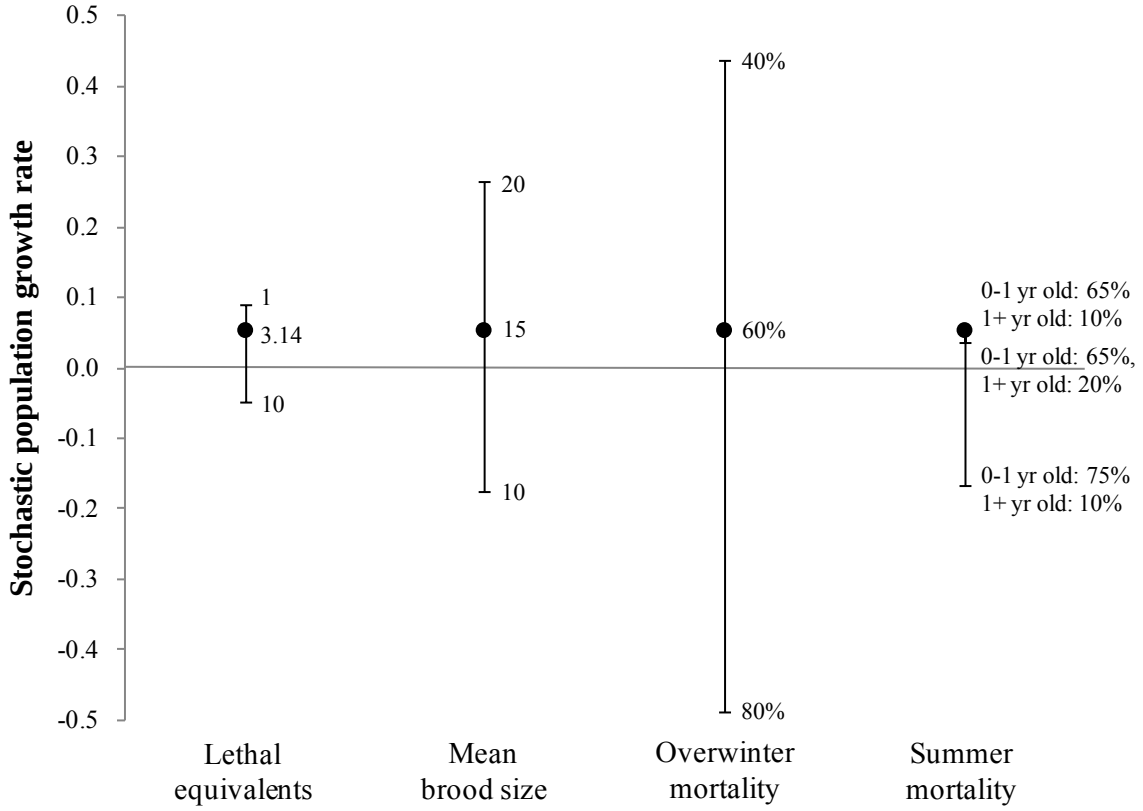
Demographic sensitivity analysis

Varying the number of lethal equivalents per individual within a biologically reasonable range resulted in relatively little fluctuation in population growth rate (Fig. 2). However, an extremely high rate of inbreeding likely would result in population decline which in turn may lead to extirpation. Adjusting the mean number of metamorphs produced per individual female by ±5 resulted in a more significant impact on population growth. Management activities or environmental impacts that alter reproductive success of NCF's by even small amounts may result in large shifts in population viability. Fluctuations in overwintering mortality also may result in extreme shifts in long-term population stability. Therefore, efforts should be made to mitigate abnormally high levels of overwintering mortality. During summer months when NCF are active, the impact of increased mortality on population stability varies with life stage. Increasing mortality rate of adults (≥1 year old) by 10% would have a negligible impact on

population growth rate; however, the same rate of increase for juveniles (<1 year old) would result in population decline over time.

While this analysis may be useful for prioritizing management efforts for NCF's, it also underscores knowledge gaps pertaining to this species that need to be filled. Incorporating erroneous life history parameters into population viability analyses can lead to inaccurate population projections. This must be considered when interpreting the results of this population viability analysis. We recommend that more accurate data pertaining to NCF fecundity and mortality rates should be collected in order to refine our models.

Figure 2. Ranges of stochastic population growth produced by varying uncertain parameters of the baseline population model within biologically reasonable limits. Dots represent parameter values used in the original baseline model.

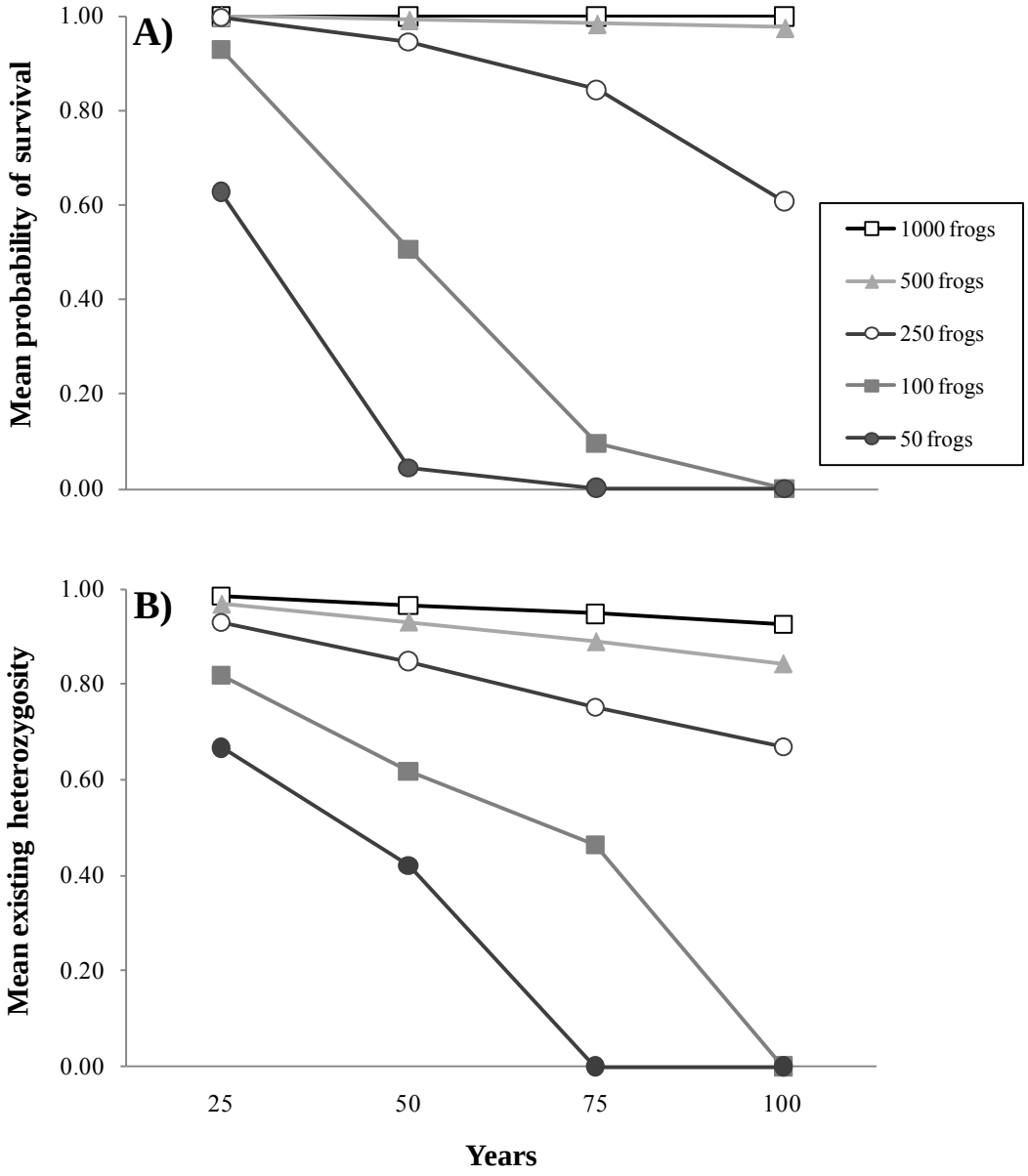


Initial population size analysis

According to the results of this analysis (see figure 3), isolated NCF populations of ≤100 frogs would decline rapidly and are 100% likely to become extirpated within 100 years. These declines would be driven by a rapid decrease in genetic heterozygosity resulting from severe inbreeding depression. A population of 250 frogs also would experience inbreeding depression, although not as severe as in smaller populations, and would have approximately a 60% chance of survival over 100 years. Over a longer time-span, a population of this size also would have a high probability of extirpation. Populations of 500 and 1000 frogs appear to be relatively stable over the time-span of the model, however slow declines in heterozygosity may eventually put

even populations of these sizes at risk of extirpation. Based on these results, maintaining isolated populations of >1000 frogs is recommended to maximize the potential of long-term stability. Alternatively, management actions that link isolated populations by establishing dispersal corridors may help to stabilize individual groups of frogs through metapopulation dynamics. It should be kept in mind that this analysis did not incorporate actual inbreeding data on NCF and is therefore only an approximation of reality. These estimates could be greatly improved if genetic data pertaining to this species was incorporated into the model.

Figure 3. Impact of initial population size on A) mean probability of survival and B) mean existing heterozygosity of a model NCF population over 100 years. Mean values were calculated based on results of 500 model iterations.



Metapopulation analysis

Without an influx of individuals and associated genetic diversity, small isolated populations of NCF have little chance of long-term survival (Fig. 4A). When linked to a second small population, the probability of survival of a small population over 100 years increases to approximately 60-70% depending on the rate of dispersal. However, long-term genetic stability is not maintained under this scenario and therefore the original small population is likely to be extirpated over a longer time frame (Fig. 4B). Regardless of the size of the secondary population there are still losses in overall heterozygosity, but medium and large secondary populations generally lead to more stable small populations. It is interesting to note that the results of our metapopulation simulations indicated that source-sink dynamics may occur when medium and large-sized populations are linked to small populations with a high rate of dispersal. The small population is stabilized by individuals and genetic material provided by the larger population, but the larger population is itself at risk of decline because it is losing individuals at a higher rate than can be replaced through reproduction or dispersal from the small population. Subsequently the entire metapopulation may be at risk of decline over time. This phenomenon is demonstrated by the decline in probability of survival and heterozygosity of a small population when linked to medium and large populations under the 25% dispersal rate scenario when compared to those probabilities when rates of dispersal was lower (Fig. 4), as well as by comparing changes in population sizes over time in low and high dispersal rate scenarios (Fig. 5). It should be noted that the ability of *Vortex* to model dispersal behavior is fairly limited, and this analysis could be greatly improved if more sophisticated modeling techniques were used.

A metapopulation consisting of several small subpopulations is not as stable as a single population of equal total size (Fig. 6). Additionally, long-term viability of the metapopulation decreases as the rate of dispersal of individuals between subpopulations decreases. As exchange of individuals and genetic material declines, each subpopulation becomes closer to effectively functioning as an isolated single population. Conversely, as dispersal increases, subpopulations begin to act as a single large population. This suggests that managing NCF in large single units is most appropriate for maintaining long-term stability; however, isolated populations are vulnerable to stochastic environmental disasters or anthropogenic impacts regardless of size, and the loss of a lone population in a region would be equivalent to regional extirpation. In a metapopulation scenario where subpopulations are distributed throughout a landscape, some subpopulations may be unaffected by localized disasters and they may subsequently serve as sources to repopulate extirpated areas. Therefore, a compromise between population size and geographic proximity of populations must be reached when considering whether to manage for single isolated large populations or several small subpopulation units.

The results of the four metapopulation scenarios reinforce conclusions previously stated. In general, groups of larger populations are more likely to persist than those consisting mostly of smaller populations (Fig. 7). However, source-sink dynamics may exist between large and small populations if high dispersal rates exist. It should also be noted that in any metapopulation scenario, each subpopulation, especially those that are especially small, has a probability of becoming extirpated. These areas may then be recolonized by frogs dispersing from remaining subpopulations. With this in mind, care must be taken not to characterize stability of the species

using the status of individual subpopulations. Rather, it is more appropriate to simultaneously consider the status of all subpopulations within metapopulations over a period of time.

Figure 4. A) Likelihood of survival over 100 years and B) resulting heterozygosity of a small NCF population when it is isolated and supported via dispersal of individuals from small, medium, and large populations. Note that a single population has a zero probability of survival and therefore has no value for heterozygosity. Also note y-axis truncation.

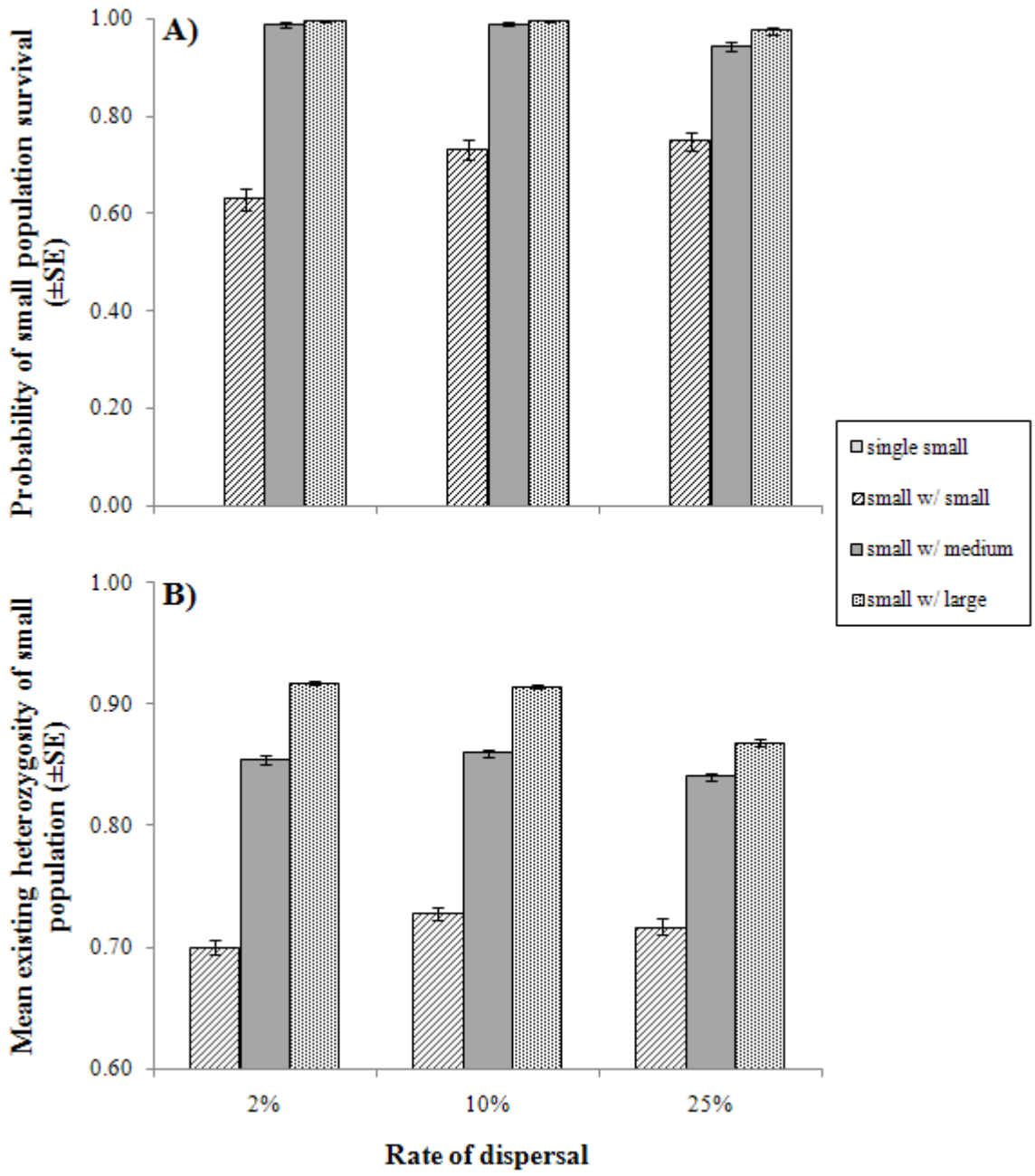


Figure 5. Relationship between rate of dispersal and long-term stability of large and small subpopulations within a NCF metapopulation.

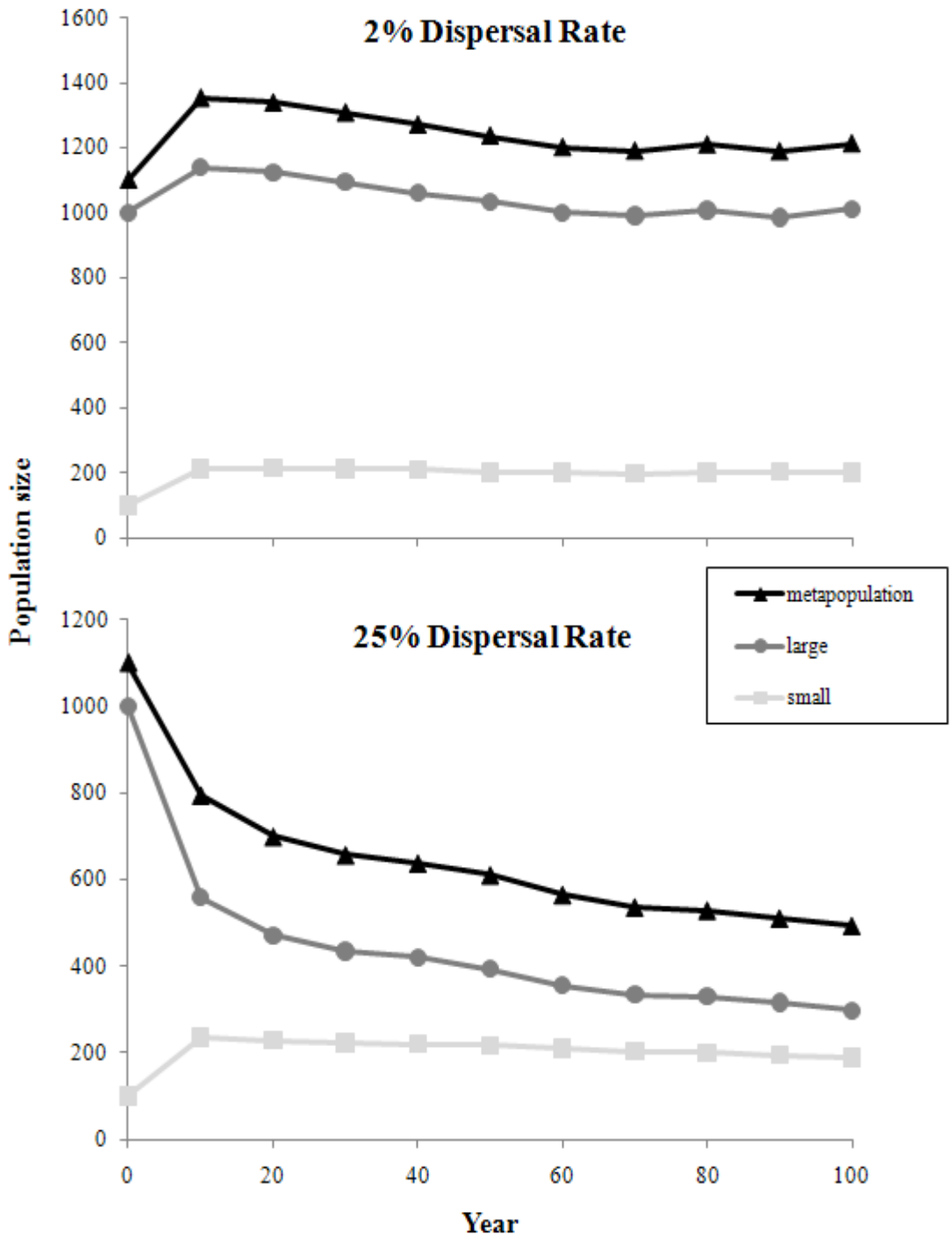


Figure 6. A) Mean probability of survival and B) mean existing heterozygosity over 100 years of a single population of 500 NCF's vs. three metapopulations of equal total size consisting of five subpopulations with 100 frogs in each with dispersal rates of 2%, 10%, and 25%. Mean values were calculated based on results of 500 model iterations. Note y-axis truncation.

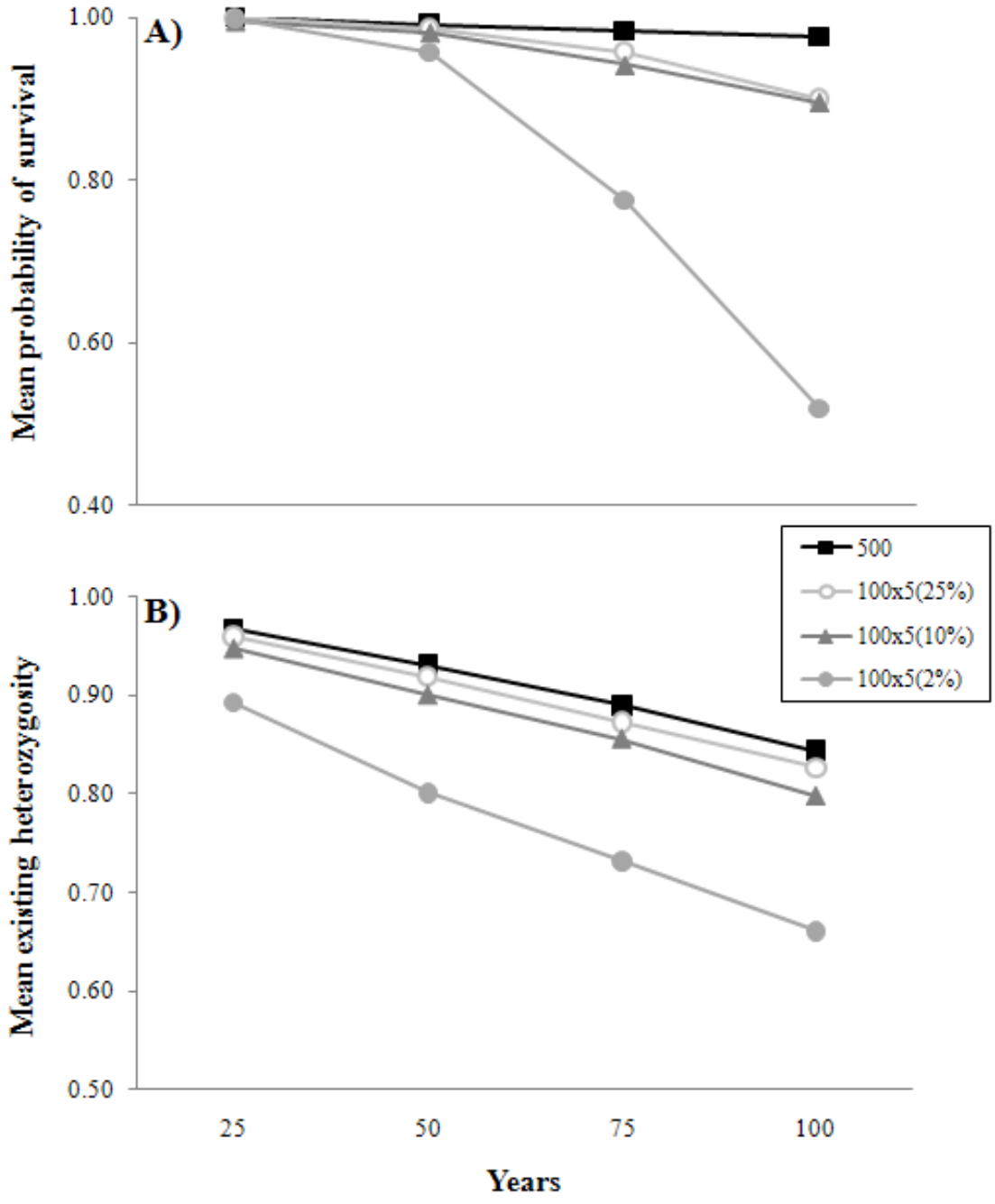
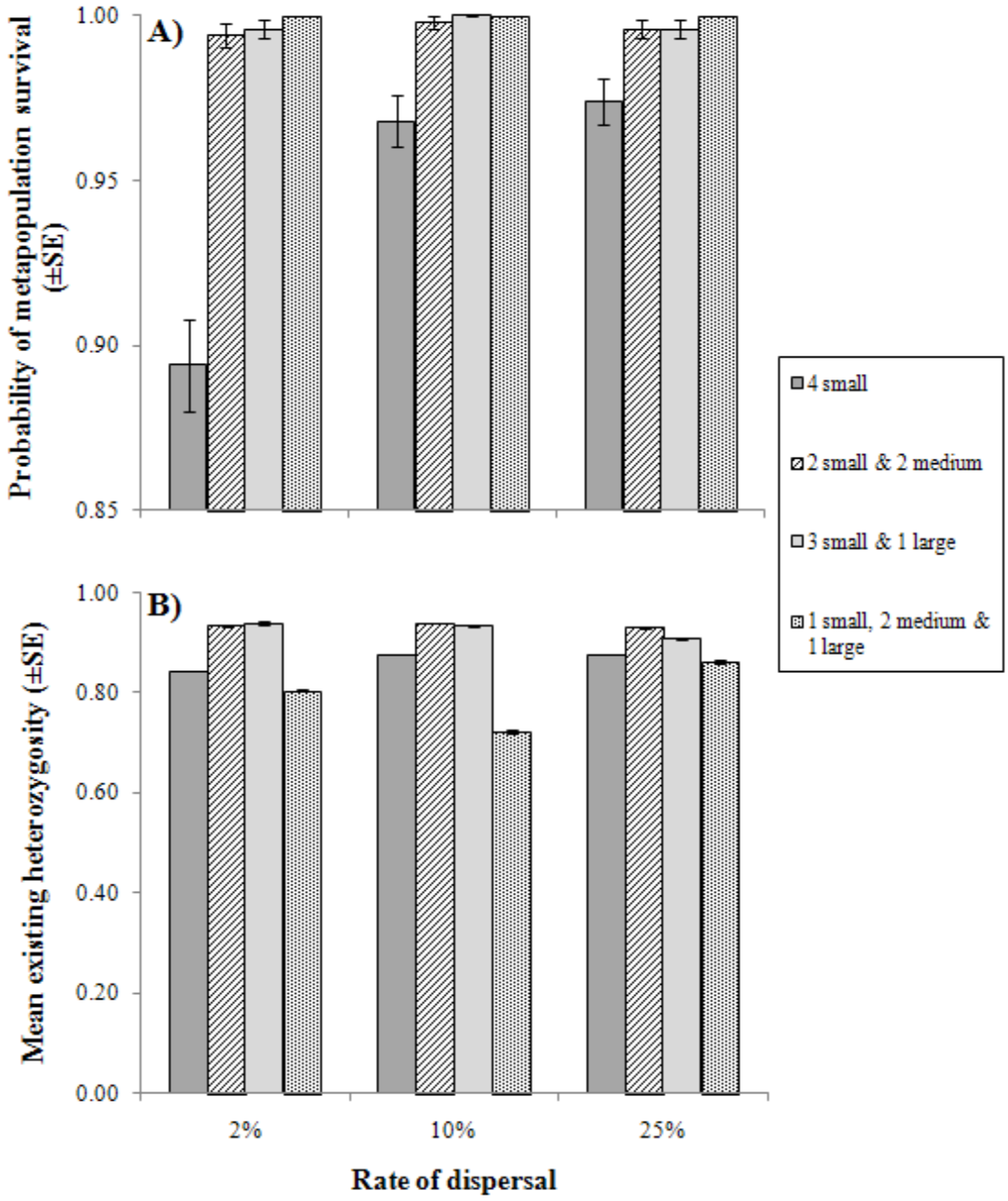


Figure 7. A) Likelihood of survival over 100 years and B) resulting heterozygosity of four NCF metapopulation models. Note y-axis truncation.



Directions for future PVA efforts

As emphasized previously in this document, the quality of information produced by any population viability analysis is dependent on the accuracy of the natural history data input into the modeling process. As additional natural history data pertaining to NCF becomes available (e.g., rates of overwintering mortality and inbreeding depression), these analyses should be repeated and the results and conclusions re-examined. Additionally, because of *Vortex's* inherent limitations in modeling dispersal behavior, more sophisticated modeling techniques should be considered to more accurately represent the impact of metapopulation dynamics on long-term population stability.

PVA's are useful for examining the impact of specific threats to population viability. When threats to NCF populations are identified (e.g., impacts of non-native predators, disease, or environmental contamination) and their precise mode of impact is known (e.g., reducing reproductive success or increasing mortality of breeding adults), PVA modeling can examine the consequences of those threats on population trends. Critical thresholds of impact can be identified beyond which populations may enter an extinction vortex, and the relative impact of multiple threats can be compared. Thus, appropriate management plans can be implemented and specific management actions can be prioritized.

Finally, when parameters of real-world NCF populations or metapopulations are known (e.g., population size and dispersal rates), the viability of these actual populations can be modeled directly, as opposed to simulated populations that may have limited comparability to specific real-world scenarios. PVA modeling can subsequently be used as a decision-making tool to compare the potential outcomes of multiple management strategies to determine the best course of action for a given NCF population.

Literature cited

Bayne, K.A. 2004. The natural history and morphology of the Eastern Cricket Frog, *Acris crepitans crepitans*, in West Virginia. M.S. thesis, Marshall University, Huntington, WV.

Berven, K.A. and T.A. Grudzien. 1990. Dispersal in the wood frog (*Rana sylvatica*): Implications for the genetic population structure. Evolution 44(8):2047-2056.

Blaustein, A. R., J. M. Kiesecker, D. P. Chivers, D. G. Hokit, A. Marco, L. K. Belden, and A. Hatch. 1998. Effects of ultraviolet radiation on amphibians: field experiments. American Zoology 38:799-812.

Burkett, R. D. 1984. An ecological study of the cricket frog, *Acris crepitans*. Pages 89-103 *in* R. A. Seigel, L. E. Hunt, J. L. Knight, L. Malaret, and N. L. Zushlag, editors. Vertebrate ecology and systematics- a tribute to Henry S. Fitch. Museum of Natural History, University of Kansas, Lawrence.

Carey, C. and C.J. Bryant. 1995. Possible interrelations among environmental toxicants, amphibian development, and decline of amphibian populations. Environmental Health Perspectives 103(Suppl 4):13-17.

Conant, R., and J. T. Collins. 1998. A field guide to the reptiles and amphibians of eastern and central North America. Third edition. Houghton Mifflin Company, Boston, Massachusetts, USA.

Dickinson, R. A. 1993. Northern cricket frog (*Acris crepitans*) survey in Ulster County, New York, 1992. Thesis, Bard College, Annandale-on-Hudson, New York, USA.

Dickson, N. J. 2002. The natural history and possible extirpation of Blanchard's cricket frog, *Acris crepitans blanchardi*, in West Virginia. Thesis, Marshall University, Huntington, West Virginia, USA.

Fellers, G. M., and C. A. Drost. 1993. Disappearance of the Cascade's frog, *Rana cascadae* at the southern end of its range, California, USA. Biological Conservation 65:177-181.

Gibbs, J. P., K. K. Whiteleather, and F. W. Schueler. 2005. Changes in frog and toad populations over 30 years in New York State. Ecological Applications 15:1148-1157.

Gray, R. 1971. Fall activity and overwintering of the cricket frog (*Acris crepitans*) in central Illinois. Copeia 1971:748-750.

Gray, R. H. 1983. Seasonal, annual, and geographic variation in color morph frequencies of the cricket frog, *Acris crepitans*, in Illinois. Copeia 1983:300-311.

Gray, R. H., and L. E. Brown. 2005. Decline of northern cricket frogs (*Acris crepitans*). Pages 47-54 *in* M. Lannoo, editor. Amphibian declines: the conservation status of United States species. University of California press, Berkeley and Los Angeles, California.

Greenwell, M., V. Beasley, and L. E. Brown. 1996. The mysterious decline of the cricket frog. Aquatica 26:48-54.

Johnson, P. T. J., and K. B. Lunde. 2005. Parasite infection and limb malformations: a growing problem in amphibian conservation. Pages 124-138 *in* M. Lannoo, editor. Amphibian declines: the conservation status of United States species. University of California press, Berkeley and Los Angeles, California.

Lacy, R.C., M. Borbat, and J.P. Pollak. 2009. Vortex: A stochastic simulation of the extinction process. Version 9.95. Chicago Zoological Society, Brookfield, IL.

Lacy, R.C., N.R. Flesness, and U.S. Seal. 1989. Puerto Rican Parrot population viability analysis and recommendations. Captive Breeding Specialist Group, Species Survival Commission, IUCN.

Leftwich, K. N., and P. D. Lilly. 1992. The effects of duration of exposure to acidic conditions on survival of *Bufo americanus* embryos. Journal of Herpetology 26:70-71.

Lehtinen, R. M. 2002. A historical study of the distribution of Blanchard's cricket frog (*Acris crepitans blanchardi*) in southeastern Michigan. Herpetological Review 33:194-197.

Leja, W. T. 1998. Aquatic habitats in the midwest: waiting for amphibian conservation initiatives. Pages 345-353 in Status and Conservation of Midwestern amphibians. M. J. Lannoo, editor. University of Iowa Press, Iowa City.

Levins, D.A. 1984. Inbreeding depression and proximity-dependent crossing in *Phlox drummondii*. Evolution 38(1):116-127.

McCallum, M. L., and S. E. Trauth. 2003. A forty-three year museum study of northern cricket frog (*Acris crepitans*) abnormalities in Arkansas: upward trends and distributions. Journal of Wildlife Diseases 39:522-528.

O'Neill. 2001. Determination of a terrestrial buffer zone for conservation of the cricket frog *Acris crepitans*. Thesis, Illionois State University, Normal, Illinois, USA.

Peter, A.K.H. 2001. Dispersal rates and distances in adult water frogs, *Rana lessonae*, *R. ridibunda*, and their hybridogentic associate *R. esculenta*. Herpetologica 57(4):449-460.

Pilliod, D.S., C.R. Peterson, and P.I. Ritson. 2002. Seasonal migration of Columbia spotted frogs (*Rana luteiventris*) among complimentary resources in a high mountain basin. Canadiaon Journal of Zoology 80:1849-1862.

Pyburn, W. F. 1958. Size and movements of a local population of cricket frogs (*Acris creptians*). Texas Journal of Science 10:325-342.

Ralls, K., J.D. Ballau, and A. Templeton. 2005. Estimates of lethal equivalents and the cost of inbreeding in mammals. Conservation Biology 2(2):185-193.

Reeder, A. L., M. O. Ruiz, A. Pessier, L. E. Brown, J. M. Levengood, C. A. Phillips, M. B. Wheeler, R. E. Warner, and V. R. Beasley. 2005. Intersexuality and the cricket frog decline: historic and geographic trends. Environmental Health Perspectives 113:261-265.

Richter, S.C., J.E. Young, G.N. Johnson, and R.A. Seigel. 2003. Stochastic variation in reproductive success of a rare frog, *Rana sevosa*: implications for conservation and for monitoring amphibian populations. Biological Conservation 111:171-177.

Seal, U.S. et al. 1990. Mexican Wolf population viability assessment. IUCN.

Skelly, D. K., E. E. Werner, and S. A. Cortwright. 1999. Long-term distributional dynamics of a Michigan amphibian assemblage. Ecology 80:2326-2337.

Spielman, D., B.W. Brook, and R. Frankham. 2004. Most species are not driven to extinction before genetic factors impact them. Proceedings of the National Academy of Sciences 101(42):15261-15264.

U.S. Fish and Wildlife Service. 2007. Chiricahua Leopard Frog (*Rana chiricahuensis*) Recovery Plan. U.S. Fish and Wildlife Service, Southwest Region, Albuquerque, NM. 149 pp. + Appendices A-M.

Van Gorp, C. D. 2001. Changes in the distribution of *Acris crepitans blanchardi*, with studies of nesting microhabitat and the possible impact of ultraviolet-B radiation. Thesis, Drake University, Des Moines, Iowa, USA.

Veldman, R.B. 1997. Trend toward extinction of the cricket frog (*Acris crepitans*): prediction of declines using field data and the Vortex simulation program. M.S. thesis, Illinois State University, Normal, IL.

APPENDIX IV

Summary of Comments Received on the draft Recovery Plan for New York State Populations of the Northern Cricket Frog (*Acris crepitans*)

Summary of Comments Received on the draft Recovery Plan for New York State Populations of the Northern Cricket Frog (*Acris crepitans*)

The Department of Environmental Conservation (hereafter, the Department) received written comments from 46 individuals and organizations, phoned-in comments from 10 individuals, and a petition signed by 167 individuals on the draft "Recovery Plan for New York State Populations of the Northern Cricket Frog (*Acris creptians*)" during the 30-day public comment period (January 22-February 21, 2014). Availability of the draft plan was announced via Department press release, the Department website, and the Environmental Notice Bulletin. All comments received were either addressed in the revised final plan or are responded to below.

Many comments expressed either general support or concerns about protecting the northern cricket frog and endangered species, in general. We reviewed the content of each comment and organized them into a set of issues. Several comments offered minor or editorial comments that were incorporated into the final draft. These changes are summarized at the end of this document.

1. **Many commenters identified sites where they think the Department should conduct surveys and/or re-introduce northern cricket frogs.**

   The department does conduct periodic acoustic surveys of known and suspected northern cricket frog habitat. All recommended areas will be considered as the department prioritizes areas for surveys.

   There has been no decision within the plan as to where or when the Department will attempt to restore populations in former locations. Prior to taking such an action, the Department would review the conditions at the site to assess why the species is no longer present. Locations for restoration would be evaluated for their suitability, including such factors as habitat quality and extent of existing protected habitat. High quality sites on public lands would be the primary target for restoration. This approach would not be limited to Long Island and would be applied across all four recovery areas.

2. **Many commenters perceived that the plan called for new regulatory protections of unoccupied habitat within 3 miles of suitable habitat for the northern cricket frog. Commenters were concerned that this new regulatory protection would cause an undue burden on homeowners, business owners, builders, local governments, and farmers.**

   The department is proposing no change in regulatory protections for areas within three miles of suitable habitat for the northern cricket frog. As stated in the plan, unoccupied habitats are not generally protected under regulatory authority so "protection must come from other methods." This is referring to non-regulatory actions such as the pursuit of land acquisition, conservation easements and cooperative agreements with landowners to manage or protect these habitats. Another avenue would be the development of landowner incentives similar to the Working Lands for Wildlife program administered by

the Natural Resource Conservation Service or the Department's own Private Landowner Incentive Program where landowners are compensated for taking beneficial management actions on their property. We would not be expanding regulatory authority to prevent building on lands referred to under this action. This action is necessary to prevent remaining populations from being completely isolated from each other. Natural movement between populations improves the quality and health of the species in New York.

3. **Many commenters pointed out that the northern cricket frog was at the edge of its range in New York. Most stated or implied that we should not be concerned if they continue to exist in New York. Some commenters suggested that the cricket frogs in New York should be relocated to southern states where they may thrive.**

   Under New York State Environmental Conservation Law (ECL) (Article 3-0301), the Department is charged with protection and management of wildlife and the preservation of endangered species. As a native frog, the cricket frog is protected wildlife as defined in ECL Article 11-0301. Additionally, under the New York State Endangered Species Law (ECL Article 11-0535), an endangered species is defined as a species seriously threatened with extinction in New York. By regulation (6 NYCRR Part 182), the Department has applied this definition only to species deemed to be native to New York (e.g., have a history of occurrence within New York attributable to naturally established populations). The cricket frog is considered part of New York's native fauna as it has been documented breeding in New York for over a hundred years. It is considered at risk of extinction within New York due to the documented decline in the number of successful breeding areas and the continued loss of essential adjacent upland habitats in several areas where they remain. If current trends continue, it is unlikely that the species would continue to persist within New York. For these reasons, cricket frogs are protected wildlife in New York, subject to the protection afforded by the New York Endangered Species Law. This plan outlines a strategy for addressing those declines and achieving a distribution that would no longer require those protections.

4. **The plan gives little or no consideration to the impact of the plan on local communities, local governments, commercial and residential property values and the property rights of landowners; surrounding uplands are currently utilized for residential, commercial and agricultural uses.**

   The plan identifies several actions in the Outreach tasks section that consider stakeholders in the vicinity of occupied and suitable cricket frog habitat. These actions include the development of Best Management Practices for landowners, a public education campaign about aquatic habitats, and improved delivery of endangered species information to county, town and village governments. Also see response to comment 15 about agricultural land uses.

5. **The northern cricket frog is not listed as an endangered species by the United States Fish and Wildlife Service (USFWS) or International Union for Conservation of Nature (IUCN).**

   It is true that the northern cricket frog is listed neither by the USFWS nor the IUCN. Under the New York State Endangered Species Law (ECL Article 11-0535), an endangered species is defined as a species seriously threatened with extinction in New York. See comment 3 for additional information.

6. **The Recovery Plan will change New York's State Environmental Quality Review (SEQR) process with regard to northern cricket frogs.**

   This plan is unlikely to significantly affect SEQR determinations. Currently, SEQR determinations already take endangered species and endangered species habitat into consideration in making a determination. The plan does not require a new three mile screening area for project review purposes to cricket frog occurrences. This plan does provide guidance on what constitutes good habitat for cricket frogs, but these habitats were already under consideration. There is no requirement for a positive declaration under SEQR for the presence of suitable habitat for listed species. The only circumstance where the Department has recommended positive declarations to lead agencies solely in regards to listed species is if the habitat impacted by the proposed project were occupied by the endangered species. This would mean that the Department has data showing that the species uses habitat on or in proximity to the property in question, consistent with the Department's response under existing regulatory authority.

7. **What funding sources will be used to implement the plan**

   There is currently a State Wildlife Grant awarded to New York State through the US Fish and Wildlife Service that provides financial support to identify northern cricket frog upland habitat requirements through 2017.

   After the plan is adopted, a work plan for implementation that defines future funding needs will be drafted.

8. **A number of commenters either supported or opposed the reintroduction of cricket frogs on Long Island.**

   See response to comment #1.

9. **The department cannot quantify let alone account for the apparent historical decline of NCF in NY.**

   The Department is not precisely sure of exactly how many cricket frog populations have been lost in New York State. The areas where we know they have been lost, however, are identified in the plan. The reduction in populations is real, significant, and current.

10. **The Recovery Plan did not cite the 2012 Glenmere Lake Watershed Protection Plan (WMP). The WMP provides recommendations for plan implementation contrary to the recovery plan.**

    We have reviewed the recommendations of the Glenmere Lake Watershed Management Plan (Revised Feb 2012) and have not found any of the recommendations in the Watershed Plan to be inconsistent with any of the recommendations in the Recovery Plan.

11. **The department does not have the regulatory authority to develop a Recovery Plan. The Department, as an administrative body, cannot create rules that substantially increase its regulatory authority absent an act of the Legislature.**

    The Department has the regulatory authority to develop Recovery Plans for endangered species. Under Environmental Conservation Law (03-0301, 11-0103, 11-0303) the Department is charged with managing, protecting and enhancing all fish and wildlife. The Department has been producing plans to do this for decades. A recovery plan that outlines a strategy for species recovery and criteria for removal from the endangered species list are clearly supported by the Department's mandate. Additionally, this plan is does not constitute a rulemaking. The plan is not a regulatory instrument.

12. **Implement a pilot program for NCF recovery and withdraw NCF Recovery Plan.**

    The Department sees no advantage in a pilot program. The plan calls for an update every five years so as we learn more about the species we can make appropriate adjustments to the plan.

13. **Without knowing why the cricket frog is in decline in the specific geographical location it may be premature to come up with a solution to the problem.**

    The recovery plan outlines a 5 part strategy to recover the northern cricket frog and remove it from the endangered species list in New York State. The identification of exactly what mechanism(s) are causing the decline is identified as a priority task in the Recovery Plan. We do not feel that not knowing the precise reason for decline precludes the development of a plan to prevent the loss of the species.

14. **Department can develop outreach tasks with relative ease and minimal expense.**

    We agree that these are tasks that should be a high priority for completion. Their inclusion in the plan will help increase their priority in Department work planning.

15. **The Plan must not negatively impact agricultural operations in Orange County.**

    6 NYCRR Part 182 guides the Department's regulatory protection of endangered and threatened species of fish and wildlife. Section 182.13 specifically exempts "existing,

routine and ongoing agricultural activities" from the permit requirements outlined in the regulation. The Recovery Plan will not change that exemption. See also the answer to comment #3.

16. The Plan notes that 1840 amphibian species worldwide are threatened or extinct. Do other recovery plans exist in NY for some of the remaining endangered amphibians?

Of those 1840 imperiled amphibian species, only two exist in New York State: the northern cricket frog and the tiger salamander. Both of these species are listed as endangered in New York State. A recovery plan for the tiger salamander is being considered.

17. The NCF survival at Glenmere Lake is largely due to the infiltration of waste from the defective leach fields in the Glenmere Homesites area of the Town of Warwick that insulate the frog during heavy, cold winters. Otherwise, it would freeze due to its inability to accumulate low molecular weight carbohydrates as cryoprotectants to assist in limiting freezing of extracellular fluids.

The Department does not concur that survival of northern cricket frogs at Glenmere Lake is largely due to the infiltration of waste from defective leach fields in the Glenmere Homesites area of the Town of Warwick. A discussion of the wintering biology of the northern cricket frog is contained in the Recovery Plan in the Non-breeding biology section.

18. Glenmere Homesites is the only area your studies have shown to have large populations of the frog.

The Department has identified large numbers of northern cricket frogs in and around Glenmere Lake, not limited to the Glenmere Homesites area. The Department has identified large numbers of calling frogs at Little Dam Lake, Lily Lake, Grand Ponds, Pine Hole Bog and Long Pond.

19. This plan appears to concentrate too much on trying to engender new NCF populations in more easily protected areas as opposed to performing the more difficult but more ecologically effective task of protecting the large areas within NYS where NCF persist.

The Department will continue to protect the occupied habitat of the northern cricket frog as outlined in 6 NYCRR Part 182. New northern cricket frog populations will only be considered after additional planning is completed and the criteria outlined in the task are met.

20. The plan should focus its efforts on protecting extant NCF habitat, especially the Glenmere Reservoir parcel, a municipally-owned wild area that the municipality, Orange County NY, is likely to sell in the very near future. A more ecologically sound approach might be to research grant funding through organizations such as

the Open Space Institute, the Trust for Public Land, etc., for NYSDEC purchase of this parcel.

The Department will continue to protect the occupied habitat of the northern cricket frog as outlined in 6 NYCRR Part 182. Fee title acquisition for conservation purposes for occupied northern cricket frog habitats is identified as a management task for immediate completion.

21. **The contributions of the New York Natural History Council (NYNH) are grossly undercredited in the plan; NYNH was the first to suggest significant distance upland brumation in this sp. In fact, numerous NYSDEC employees argued against this observation and were, ironically, later credited for it.**

    The authors primarily used published research to support this document. Gray literature and personal communication were used where we felt appropriate.

22. **NYSDEC approach to NCF research has given more credit to those researchers who work for firms that are routinely retained by pro-development interests over unbiased research NGOs such as NYNH. Until this trend is reversed, poor science may overshadow good.**

    NYSDEC staff has conducted some research to learn more about the winter habitat requirements of the northern cricket frog. The authors primarily used published research to support this document. Gray literature and personal communication were used where we felt appropriate.

Editorial changes made:

Page iv: Affiliation of Scott Angus changed to Northeastern Partners for Amphibian and Reptile Conservation.
Page 3: Added “relatively”
Page 7: Added “infrastructure”
Page 8: Removed extra “and”
Page 9: Replaced “theory” with “hypothesis”
Pages 11 and 12: Updated Latin names to reflect recent changes