Vermont

Timber Rattlesnake

Recovery Plan

July 2015

Vermont Fish and Wildlife Department

Agency of Natural Resources

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Cover Photo: gestating gravid female - Ryan Smith, Vermont Fish and Wildlife Department

EXECUTIVE SUMMARY

The Vermont Endangered Species Law establishes authority for the protection of those species and their respective habitats that are listed as endangered or threatened. Authority and responsibility for the development and implementation of species recovery plans in Vermont rests with the Secretary of the Agency of Natural Resources and the Commissioner of the Fish and Wildlife Department. Recovery of species listed pursuant to this law is contemplated as a primary objective. Ultimately, the goal of the State of Vermont is to recover species listed under the Vermont Endangered Species Law to a level that they can be delisted and support viable populations for the long-term survival and integrity of the species.

In 1987, the timber rattlesnake (*Crotalus horridus*) was designated as an endangered species in Vermont. Previous to that time, the species had suffered a significant decline in range and numbers due to bounties, human persecution, and habitat loss. Today this species still suffers from habitat loss and persecution throughout its range while it also faces a new, very ominous threat from a lethal disease commonly known as Snake Fungal Disease. In 2012, the newly emerging skin fungus *Ophidiomyces ophiodiicola* (*Oo*) was detected and subsequently confirmed in Vermont rattlesnakes. This disease may prove to have significant, negative impacts related to the state's endangered rattlesnake population as it has the potential to overwhelm recovery efforts or other conservation actions on its behalf.

Timber rattlesnakes are characterized by long life span, late maturation, low reproductive output, and a consequently slow turnover in population. These animals have a preference for low-elevation, oak-hickory-hop hornbeam forest communities and undeveloped areas with thermally favorable rocky slopes and/or exposed ledges for basking. Vermont's population is currently estimated at several hundred animals. Habitat loss and degradation, disease, human disturbance and persecution threaten the long-term viability of the species in the state.

This document provides an overview of timber rattlesnake biology, population condition, threats, research needs, and ongoing management efforts specific to Vermont. Specific recovery objectives are also identified, each of which must be satisfied in order for recovery to be considered successful, and thus secure the long-term viability and sustainability of the population. Additionally, the report provides a comprehensive recovery plan that lists those actions identified as most likely to ensure the long-term viability and growth of Vermont's rattlesnake population. The goal is to recover this snake population to a sustainable and secure population level that will justify de-listing from the Vermont list of endangered and threatened species. However, due to pervasive negative human attitudes, fear, and persecution towards this species the recovery objectives required for delisting may not be achievable. Management actions recommend a focus on determining population demographic information, disease and genetic exchange monitoring, increasing population recruitment, identifying, conserving and enhancing additional critical habitat areas, continuing efforts to protect animals from persecution and disturbance, as well as persistent educational/outreach efforts to promote landowner stewardship and raise public awareness of, and appreciation for the conservation value of this unique species.

In addition to satisfying the required demographic criteria, social considerations are vital to the recovery process. Achieving these objectives will require collaboration and support from a

variety of public partners including local residents, schools, conservation organizations, conservation commissions and town planning boards. Lastly, key partnerships will need to be continued with universities, natural resource professionals and laboratories to facilitate low-impact research to monitor the status and welfare of timber rattlesnakes in Vermont.

Recovery Goals

The recovery goals for Vermont populations of timber rattlesnakes are to:

1. Secure and enhance known populations of the timber rattlesnake to levels that can safely provide for long-term population stability across the historic range of rattlesnakes in Vermont.

2. Provide a sufficient quantity of high quality, conserved habitat to support these populations.

3. Remove the timber rattlesnake from the Vermont list of threatened and endangered species.

Recovery Objectives

Criteria for Downlisting from Endangered to Threatened *(full text on page 31)*

1) At least three functioning metapopulations that are conserved.

2) Must have a statewide total of >200 adult females which persists over a 10-year period.

3) Sufficient levels of successful breeding/recruitment must be achieved and sustained, combined with adequate age class diversity.

Criteria for Delisting from Threatened

1) At least four functioning metapopulations that are conserved.

2) Must have a statewide total of >400 adult females which persists over a 10-year period.

3) Sufficient levels of successful breeding/recruitment must be achieved and sustained, combined with adequate age class diversity.

NATURAL HISTORY AND ECOLOGY

Taxonomy, Species Description, and Distinguishing Characteristics

The timber rattlesnake (*Crotalus horridus*) is one of 32 species of rattlesnakes worldwide. All are found in the western hemisphere (Rubio 1998) with the timber rattlesnake being one of 15 rattlesnake species found in North America (Behler 1979). The word Crotalus is from the Greek work crotala, meaning "castanet" or "musical rattle." Depending on the source, the specific epithet horridus is defined as "rough," "bristling," "scaly," or "dreadful". The rattlesnake's range and population have undergone extensive declines during the latter half of the twentieth century, particularly in New England, due to habitat loss, fragmentation and human persecution. The rattlesnake is Vermont's only venomous snake and perhaps is its most misunderstood snake (Mitchell 1994). The species was designated as endangered in Vermont in 1987, and currently, the timber rattler is limited to two small, discrete populations in the state.

The timber rattlesnake is in the order Squamata, suborder Serpentes, family Viperidae, (subfamily Crotalinae, or pitvipers) (Conant and Collins 1998). Rattlesnakes exhibit several features that, in combination, separate them from all other snakes found in North America. The rattle is the unique feature characterizing the two genera *Crotalus* and *Sistrurus*. These two genera are distinguished by the size of the scales on the forward half of the top of their head (Rubio 1998, Klauber 1982). Rattlesnakes in the genus *Crotalus* have a series of small, similarly shaped scales. Rattlesnakes are born with a skin cap on the tail tip, called a prebutton. Within about ten days of its birth the skin is shed and an underlying button replaces the prebutton. Each time the rattlesnake sheds; a new rattle segment is added to the rattle. A wild rattlesnake rarely has all its rattle segments, as they often break off (Rubio 1998). There are many hypotheses regarding the rattle's function, but the most widely accepted hypothesis is that the rattle is useful in warding off predators and large grazers through its sound.

Another feature of rattlesnakes is the pit organ, a small facial cavity between the eye and the nostril on each side of its head. This is a distinguishing feature of all pit vipers. A heat-radiation-detecting membrane is within the pit, functioning as a locating and homing device. The primary function of this pit organ is the detection of warm-blooded prey and predators (Rubio 1998).

Rattlesnakes have a pair of long, hollow, retractable fangs. These fangs are attached to the front of the maxillary bones and are connected to venom glands (Klauber 1982). The fangs fold back inside an oral membrane within the roof of the mouth when the mouth is closed. When the rattlesnake strikes, the teeth are swung down and forward to aid in penetration of the prey. As the snake strikes, the mouth closes slightly, helping to aid the insertion of the fangs into the prey's body. Rattlesnake heads are triangular or spear-shaped, to accommodate their venom glands, venom injecting apparatus, and loreal organ.

Snake venom is composed of a variety of chemical compounds, primarily polypeptides and enzymes, and is a complex and toxic substance. Venom allows the rattlesnake to secure food and also aids in digestion (Klauber 1982). Venom is not unique to rattlesnakes -- other snakes have venom capabilities. Venom is highly evolved saliva, and in general terms can be described either

as hemotoxic (prevents blood coagulation while destroying vessels) or neurotoxic (acts on nervous system, causing paralysis and heart and respiratory malfunction). There are varying amounts of these toxins in rattlesnake venom depending on species, range, and the age of the snake (Grenard 2000, Rubio 1998). There is some discussion in the scientific literature that rattlesnake venom changes as prey develop defenses against the venom (Grenard 2000). Timber rattlesnakes are generally considered hemotoxic but also have some neurotoxic components (Klauber 1982). When a rattlesnake's fangs enter its victim, venom travels from a venom duct through the hollow fang and into the prey and usually causes a severe physiological response in the body. Venom travels through the prey's body using the prey's circulatory system or its lymphatic vessels and is quickly lethal for prey (Rubio 1998).

The timber rattlesnake is a large, thick-bodied snake with a highly variable color pattern. The background color of the timber rattlesnake ranges from yellow to black, with zigzag-shaped cross bands, often called chevrons, across its dorsal surface. These cross bands are usually outlined with a row of yellow/olive scales. The colors and patterns vary geographically (Brown 1993). In the north there are two color phases, or morphs. Yellow phase snakes have yellow heads with dark-gray to black cross bands on a yellowish to brown body. Black phase snakes have a black head and black cross bands down their dark-brown to black body (Mitchell 1994). The color of the snake darkens towards the posterior (rattle) end of the snake. Timber rattlesnakes have black or dark brown tails, sometimes with black bands. The venter of the snake is cream colored and can be peppered with black. The pattern of the snake makes it difficult to see in vegetation. The scales are heavily keeled, giving the snake a rough appearance and feel. Juveniles are patterned the same as adults, although some do have an eye-jaw stripe and a mid-dorsal stripe that usually fades as the snake ages. The cross bands on the neonate's tail are sometimes visible. As the snake grows older, pigment accumulates, making most adult tails uniformly black in color (Mitchell 1994).

Male timber rattlesnakes are larger than females. In a study in northeastern New York, Brown (1993) found average adult males (n=200) had a total length of 111 cm (43.5 inches), with a tail length of nine cm (3.5 inches). The males weighed an average of 900 g (2.0 lbs.). The largest male Brown recorded was 137.5 cm (54 inches) and weighed 1,760 g (3.9 lbs.). Brown found average adult females (n=150) had a length of 97 cm (38.5 inches), with a tail length of 6 cm (2.5 inches), with a weight of 600 g (1.3 lb.), and the largest female, pregnant (gravid) at the time, was 120 cm (47 inches) and weighed 1,414 g (3.1 lb.) Brown (1991) noted females reached maturity at approximately 84 cm (33 inches) snout-vent length. Vermont's 2010-2012 rattlesnake research study recorded its largest captured snake, a male, at a total length of 55 inches (140 cm). The heaviest male recorded in VT weighed 1915g (4.2 lbs.)(Spear et al. 2013). The maximum-recorded length of the timber rattlesnake is 189.2 cm (74 inches) (Conant and Collins 1998). In Virginia, the maximum total length is 170.5 cm (67 inches) (Mitchell 1994).

Movements

Timber rattlesnakes follow a predictable series of annual movements throughout the year: spring emergence, egress, foraging, birthing, fall ingress, and submergence. In northeastern New York, the timber rattlesnake spends about 7.4 months hibernating in its den or hibernacula, and has an active season of 4.6 months (Brown 1992). More recent phenology measurements at the same study site indicate a 6.8 month hibernation period and a 5.2 month active season (W. Brown,

personal communication). Vermont researchers observed a similar active period of approximately 5.5 months in their 2011-12 rattlesnake telemetry study. In West Virginia the average active season was found to be 4.7 months at a high elevation site (Martin 2002).

Emergence

Timber rattlesnakes have a seasonal cycle that begins with emergence from the den site. Ancestral dens used by timber rattlesnakes have been used for thousands of years (Brown 1987). These sites are where the snakes congregate in the fall to spend the winter. The snakes congregate with other timber rattlesnakes and other snake species, including the eastern ratsnake (*Pantherophis pantherophis*) (Tennant 2003). During their annual movement cycle they rarely go more than a few miles from the den site. Due to the concentration of snakes at dens and the repeated use of traditional den sites, timber rattlesnakes are especially vulnerable to poachers and malicious human activity while in the vicinity of their den.

Dr. Alcott Smith, a retired veterinarian and rattlesnake enthusiast, monitored Vermont's known denning areas for many years. During the years of 1992 -2010, Dr. Smith informally surveyed Vermont's known dens during key activity periods from approximately the third week of April to mid-October. He kept notes of his many observations over the years and, although not designed as a scientific study, his notes and knowledge of Vermont rattlesnakes and their habitats are quite extensive. According to his field notes, emergence usually occurs between mid-April and the first two weeks in May, with the exception of an early April emergence in 2010 when he saw a snake on April 3rd (A. Smith, personal communication). Table 1 shows the first date Smith saw snakes in a given year, though these dates were often the first time he visited the site. The snakes may have emerged earlier. In Vermont's recent study, average emergence dates were May 17 in 2011 and May 14 in 2012. One individual in 2012 was observed to have surfaced on March 27. (Spear et al. 2013). A study of timber rattlesnakes in the Appalachian Mountains of Virginia found no difference in timing of emergence between the sexes (Martin 1992b).

Table 1: Earliest dates that timber rattlesnakes (*Crotalus horridus*) were found at Denning Area A (DA) and Denning Area B (DB) (1992 – 2010) by Alcott Smith. Only DA was surveyed in 1992 and 1993.

Year	*DA*	*DB*
1992	5/3/92	
1993	5/1/93	
1994	5/9/94	-
1995	5/7/95	5/14/95
1996	4/21/96	5/19/96
1997	5/5/97	5/14/97
1998	4/29/98	5/12/98
1999	4/30/99	4/30/99
2000	5/27/00	5/4/00
2001	5/2/01	5/8/01
2002	4/16/02	5/6/02
2003	4/30/02	5/4/03
2004	5/12/04	5/12/04
2005	5/10/05	4/19/05
2006	4/30/06	4/20/06
2007	4/23/07	2/22/07
2008	5/10/08	4/18/08
2009	4/28/09	4/25/09
2010	5/01/10	4/03/10

According to bounty records from West Haven, the earliest a bounty was paid was April 22 (1932), and there are considerable records from the first week of May. The latest bounty paid in West Haven was October 11 (1924), and in Fair Haven, the latest record was October 19 (1899) (Andrews and Cillo, unpublished data).

In northeastern New York, between 1981 and 1988, the earliest date of emergence was April 8 and the latest ingress date was October 16 (Brown 1992). This very early April date was unusual, and over the period of the study only 6.2% of the spring records were from April (Brown 1992). Brown found the median date of spring captures was May 13, and he considers the 15-day span from May 7 to May 21 to be the period of emergence for that population (Brown 1992). Egress is very dependent on temperature and wind and Brown (1992) found that most snakes emerged when the daily temperature exceeded 15˚ C.

Egress

After emergence and after the timber rattlesnakes have raised their body temperatures sufficiently, they move away from their denning area and towards foraging or birthing areas. Some individuals move away from the den site relatively quickly, while others, often gravid and post-partum females use the exposed rocks around the den for basking (Martin 1992b). Some egress routes in Vermont are used regularly year after year.

Foraging/Home Range

Foraging occurs throughout the active season for males and non-gravid females. Their foraging activities take them well away from the denning area and occasionally to people's backyards. In Vermont the majority of monitored rattlesnakes moved away from their hibernacula generally in mid-May, then utilized one or more core areas within a relatively stable distance from the hibernacula, and subsequently returned to the same den in the fall. The home range size of telemetered snakes varied depending upon the calculation method used and ranged from 894 ha (95% fixed kernel UD) to 199 ha using the MCP method. (Appendix Table 2 shows annual home range size depending on the calculation method used. (Spear et al. 2013) For a population of timber rattlesnakes in New Jersey, the approximate area used by a male timber rattlesnake during the entire active season was 124 ha (306 acres) as compared to a female (gravid or non-gravid) whose activity range averaged 14 ha (35 acres) (Zappalorti and Reinert 1992). A study of timber rattlesnakes in Nebraska found the mean migratory distance from the den was 3.4 km (2.1 miles), with a significant difference between males and females (Fogell and Fawcett 2005). In northeastern New York, Brown (1993) found the maximum seasonal migratory distance was 7.2 km (4.5 miles) for a male timber rattlesnake and 3.7 km (2.3 miles) for a non-gravid female. The mean migratory distance from the den was 4.07 km for males (2.5 miles) and 2.05 km (1.3 mi.) for non-gravid females (Brown 1993). Spear et al. (2013) documented mean maximum migratory distance from Vermont dens of 3.18 km (1.98 mi.) with males moving further (3.56 km/2.2 mi.) versus non-gravid females (2.28km/1.4 mi.). The greatest displacement distance moved from a hibernaculum was 5.72 km (3.6 mi) by a male in 2012. Two pregnant females displayed the shortest displacement distances of 1.41km (0.88 mi.) and 1.25 km (0.78 mi.)

Birthing

Timber rattlesnakes bear live young. Gravid females search out birthing rocks for cover and to raise their body temperatures. In Vermont, these are large flat rocks that soak up a great deal of sun. These birthing rocks are used year after year and females using them can be very vulnerable during this time. Spear et al. (2013) reported 10 (27%) of the 37 adult females captured during the two-year Vermont study were gravid. Evidence of birthing was observed from the third week in August through the last week in September. A variation in summer ambient temperature or elevation can change parturition dates appreciably (Martin 1992b, A. Smith, personal communication).

Ingress and submergence

Ingress (traveling back to the den site), and submergence (entering the den), occur in September and October. Timber rattlesnakes can often be found in the vicinity of their den site basking on the last warm sunny days of early fall. The neonates of the year will follow adult scent trails to their den site. As the weather gets colder, the snakes submerge to where the temperatures do not drop below freezing. Martin found solitary or small groups of neonates hibernating separately from adults at one study site, but at another study site all age classes wintered together (Martin 2002). The smaller snakes can travel to different parts of the dens, and perhaps reach lower sectors in the den because their bodies are smaller (Martin 1992b). In Vermont, timber rattlesnakes generally head back to the den site in preparation to enter the den in late September to mid-October. Average ingress dates in 2011 and 2012 were Sept. 29 and Sept. 13 respectively with the latest captures occurring on Oct.12, 2011 and October 17, 2012. One juvenile rattlesnake in 2011 was observed outside the den on Nov. 8. (Spear et al. 2013). The latest

basking recorded was mid-November in Vermont (DesMeules 1995). In William S. Brown's study in northeastern New York, September 17 was the median date of ingress and he considered September 14 to October 1 to be the general ingress period (Brown 1992). He also found that October 1st seemed to be the latest date that snakes would be found farther than a day's travel from a den. Few snakes were captured between October 2 and October 8; the last date a snake was captured was October 16.

Food Habits

Like all snakes, timber rattlesnakes are carnivorous. They swallow their prey whole after killing it. They are primarily ambush or "sit and wait" hunters. They will often rest their head on or near a fallen log used as a pathway by chipmunks (*Tamias* sp.*)* or mice (*Peromyscus* spp., *Napaeozapus* sp.) (Brown and Greenberg 1992). The snake will wait until a rodent passes and then strike quickly, sinking its fangs into the body, envenomating the prey and then releasing the animal. Using its vomeronasal organs and tongue, the snake follows the injected prey. When found, the snake starts consuming the animal headfirst (Rubio 1998). Rattlesnakes also will occasionally seek out prey by following a scent trail. They may rarely take carrion, and it appears the smell of a decaying animal is an attractant (Rubio 1998). In captivity, timber rattlesnakes will eat pre-killed animals (Martin 1992b, E. Talmage, personal communication).

Clark (2002) synthesized information in the literature and examined the stomach contents of museum specimens to explore the snake's diet. He examined 1,108 specimens and found food in 178 snakes, with a total of 179 prey items found. He incorporated 400 literature records of prey taken by timber rattlesnakes. The diet of timber rattlesnakes from the north differed from those in the south. In addition he found that larger snakes take larger prey, but do not eliminate the smaller prey from their diet. Clark found that 91.1% of the species' diet was mammals, 7.2% birds, 1.2% reptiles, and 0.3% amphibians. For the northern group, the top mammal species found were *Peromyscus* (new world mice) (34.9% of total prey items), *Microtus* (voles) (14.1%), *Tamias* (Chipmunks) (13.5%), *Sylvilagus* (Cottontail Rabbit) (8.6%), *Clethrionomys gapperi* (Red-backed Vole) (4.4%), *Sciurus* (Squirrels) (3.3%), *Napaeozapus insignis* (Woodland Jumping Mouse) (3.3%), and *Sorex* (Shrews) 2.2% (Clark 2002). Snakes in the north eat significantly more *Microtus, Tamias, Napaeozapus*, and *Clethrionomys* than those in the south. He also found that juvenile snakes feed mainly on mammals with a mass of 25 grams or less and adults feed mainly on mammals with a mass of 35 grams and more (Clark 2002).

Timber rattlesnakes eat a significant number of rodents each year. The timber rattlesnake's method of sitting and waiting for prey separates it behaviorally from predatory mammals and birds of prey. These three groups of predators "may together contribute to a more balanced regulation of prey populations than any one group could contribute alone" (Brown 1988).

Mating, Birthing, and Fecundity

Timber rattlesnakes are considered a "K-selected" species, characterized by long life span, late maturation, low reproductive output, and a consequently slow turnover in population.

The age of sexual maturity varies between males and females, generally between six and 11 years for females and four to seven for males (Harding 2000). In Vermont, mating usually occurs in mid-July to early September after the snake's annual shed (generally in late May through June

(Spear et al. 2013). At this point the females release pheromones and the males stop foraging and start searching for them. When two males meet they may engage in a combat dance, which is described in some detail in Klauber (1982) and in Merrow and Aubertin (2005). When a male finds a female, the courtship involves tongue flicking, head nudging, and, while engaging in these activities, he also jerks the posterior part of his body while curling his tail around the female's until the female raises her tail and copulation can occur. Copulation lasts generally one to two hours, but can continue for much longer (Klauber 1982, A. Smith, personal communication).

In a study in Ohio, copulating snakes were seen on July 31 and August 27 (Coupe 2002). Coupe discusses three hypotheses as to how the male locates the female for mating: (1) scent trailing - either a male following a female or a male following another male to a female; (2) prior experience – a snake's knowledge of where females had been previously; (3) use of efficient search patterns – a snake searches until he finds a female ready to mate. No single hypothesis was completely supported by the data (Coupe 2002).

Vermont researchers witnessed mating on numerous occasions in summer of 2012 with a pair of snakes seen mating on July 25, two additional pairs mating on August 3, a pair on August 20 and another pair on August 24.

The female will store the sperm throughout the winter, and late in May the sperm are released, and fertilization occurs. Gestation is generally 90 days, but can extend to four months (Martin 1992b). During gestation, the female does not usually eat, and she may lose an average of 40% of her body weight at parturition (Brown 1995). Ovoviviparous embryos develop within the mother snake, yet are not intimately connected via a placenta like a fully viviparous embryo. Rattlesnakes bear live young. A young snake is born in about 20 minutes with roughly one-hour intervals between neonates. As with many other terrestrial vertebrates, they are wrapped in a chorioallantoic membrane and after a few minutes the young start moving and poking to get out of their membrane (A. Smith, personal communication). The mother stays with the young for varying lengths of time, between a few hours to several days after the neonates' first shed (Klauber 1982, Mitchell 1994). Regardless of the length of the stay, timber rattlesnakes are an exception to the pattern exhibited by most snakes in Vermont, as they are apparently the only snake species to exhibit any maternal care. Young are precocial, and can take care of themselves immediately after birth; however maternal care may enhance early survival of the neonates.

In Martin's (2002) 12-year study (1989 – 2001) in West Virginia, the youngest female mated at eight years old and gave birth the following fall. Typically he found reproduction in both the males and females to occur by 10 years old or older (Martin 2002). Martin found pregnant females to be hard to locate in early June, but by late June they were more likely to be seen around the birthing sites. He found 29 litters of pre-shed neonates as early as August 31 and as late as October 4. In addition, the latest date a pregnant female was found was October 7 (Martin 2002). Females do not breed every year, and in the population Martin was studying he found the number of years between births was three to eight (average of 5.2 years). The average number of offspring per litter was 8.8 (range 6-14).

Nearer to Vermont, and in an environment relatively similar, Brown (1991) found that for a population of timber rattlesnakes in northeastern New York, the age of first reproduction for

females ranged from seven to 11 years with an average of 9.3 years. He also found that for 30 females with definitive reproductive cycles – a reproductive cycle whose length was ascertained -- 57% were triennial, 27% were at least quadrennial and 6% were at least five years or longer (Brown, 1991). The females of this population delivered about nine young per brood, but ranged from 4-14). The average sex ratio at birth is 1:1 (Brown 1993). It's likely that the population in Vermont reproduces at a similar rate to the northeastern New York population. Spear et al. (2013) reports the number of follicles per gravid female in Vermont averaged 5.7 +/-1.14 and ranged from 1 to 12.

Following the neonates first shed (approx.10-14 days) the young-of-year snakes make their way to their overwintering den by following the scent trail of their mother and other adults. At this time the young-of-year snakes are quite vulnerable to predation from a variety of predators including canids such as coyotes and foxes, hawks and other raptors, North American racers (*Coluber constrictor)* and occasionally, wild turkeys (*Melleagris gallopavo silvestris).*

Longevity

Once reaching adulthood, a timber rattlesnake's average lifespan is approximately 20-25 years (Brown 1993), although in captivity, and occasionally in the wild, they have been found to live 35 years or more (Rubio 1998). Martin (2002) found two snakes in the population he was studying to be a minimum of 24 and 26 years of age and due to the high number of old adults, he speculated a maximum longevity of 35 years. Cavanaugh (1994) reported one individual that lived in captivity for 36 years, 7 months and 27 days. Most recently in 2012, Brown documented re-capturing two individuals (male and female) in the wild, each in excess of 40 years of age. (W. Brown personal communication) Brown et al. (2007) estimates a 65%-68% survivorship during the snake's first year, and a 90% survival rate as adults.

While the Vermont researchers captured numerous snakes estimated to be in their twenties, the age structure and longevity of Vermont's population is not yet determined.

Human Fears

There is a great deal of fear associated with rattlesnakes, however, this fear is largely out of proportion to the actual level of risk. It's this heightened level of fear which has contributed greatly to the near extermination of rattlesnakes over much of their former range.

Timber rattlesnakes are generally described as docile and timid. They're fairly reclusive, and readily rely on camouflage for protection or escape. Like most wild animals, timber rattlesnakes will protect themselves when cornered or handled, but generally do not strike unless provoked (Brown 1988). In most casual encounters a rattlesnake generally stays still to avoid detection or moves out of the way of humans as it attempts to avoid confrontation whenever possible. Only as a last resort, when cornered, threatened or harassed would a snake strike in self-defense.

In 1997 a study was published examining deaths resulting from animal attacks in the United States from 1979 to 1990 (Langley and Morrow 1997). Of the 1,882 animal-related deaths, snakes caused 66, dogs caused 186, and bees and hornets caused 527. There were an average of 5.5 human fatalities per year caused by snakes with a death rate of 0.023 per million per year. The study further teased out information about the deaths and found that male humans composed

74.3% of the deaths and a significant majority of those were young white, stupid males (Langley and Morrow 1997). Timber rattlesnakes will sometimes give a so-called "dry bite" (no venom injected). The number of dry bites was estimated to be approximately 20% of all rattlesnake bites (Langley and Morrow 1997). In another study, 15% of rattlesnake bites treated in a 10-month period in Phoenix, Arizona, were from dead snakes that had "been decapitated, shot or whomped until dead." The doctors doing the Arizona study said of the people who had gotten bitten that "none displayed what he (the doctor) would consider to be good judgment" (O'Neil 1999, Suchard and LoVecchio 1999).

In Vermont, there are no definitive records of any deaths caused by a timber rattlesnake. The only mention of a snakebite death is from a tombstone in Putney that reads "killed by a serpent." There are no dates provided, and it is not known where the incident happened (Pfeiffer 1990). There are also very few accounts of bites. There are three historic Vermont records of snakebites alleged to have occurred in the wild over the last 200 years. The first, from Bristol, occurred in the early 1800s and happened as two brothers were trying to kill the snake (Munsill 1979). The second, occurring in 1959 in Ludlow, resulted in the patient having no serious effects, although she was hospitalized (Anon. 1959, E. Bont, personal communication). There was a possible venomous snakebite in Poultney in 2003, although no snake was seen (G. Balestra, personal communication) raising some doubt of this being from a rattlesnake. Quite recently, in July of 2010, a confirmed incident of a rattlesnake bite occurred in Fair Haven with a 46 year-old male resident of that town. The man was bitten on the hand apparently attempting to handle the rattlesnake, allegedly while "trying to assist the snake across the road." The bite was serious and required treatment and hospitalization at the Rutland, Vermont hospital.

In 2005, a dog was reportedly bitten by a venomous snake on Ginseng Hill, an area west of Brattleboro (Windham County) with an elevation of 1,300 feet. A two-year-old dog had two puncture marks below its eye. The dog later died. The owner had recently brought stone up from Goshen Massachusetts for landscaping (S. Parren, personal communication).Goshen is in Hampshire County, Massachusetts where timber rattlesnakes have been found (Cardoza and Mirick 2000), although Goshen is not near a known den (S. Parren, personal communication). Dr. William S. Brown thinks that bites such as these are more likely from stowaway copperhead snakes (W. Brown, personal communication).

During the days of bounty hunting (legal until 1971), stories appeared in local Vermont newspapers regarding hunting the snakes. During the 1950's L. Reed related killing 22 or 23 in a day, while his friend Charles Mingo was quoted "I've been around them since I was a boy and if they possibly can, they will get away. I've even teased them with a stick. If you give them a chance, they'll get away. The only time they strike is when you step on one" (Bland 1968). Overall, the risk of a timber rattlesnake bite is very low and the fear surrounding them is far out of proportion to the level of risk. Envenomation from a timber rattlesnake is potentially dangerous, but being bitten is extremely unusual and easily avoided. Education is an effective way to limit risks, remove some of the fear, and lower the risk of unnecessary snake killings by misinformed or fearful people.

Milksnakes (*Lampropeltis triangulum*) are regularly misidentified as timber rattlesnakes because they often coil, strike, and vibrate their tails in a manner that can produce a convincing rattling noise. In addition, they have blotches rather than the striped pattern that most Vermonters are

used to seeing on our very common garter snakes. Other local snakes such as the North American racer (*Coluber constrictor)* can also produce a very convincing rattling noise with their tails. Northern watersnakes (*Nerodia sipedon)* don't rattle but they do have a thick, banded body and rough scales of a rattlesnake and sometimes are mistaken for rattlesnakes. Milksnakes are clearly responsible for most of the suspect reports of rattlesnakes received from many areas of Vermont not known to have rattlesnake populations.

HABITAT REQUIREMENTS

In the northern part of their range, timber rattlesnakes are generally found on mountainous slopes (below 1,300 ft.) with steep ledges, talus slopes, and rocky outcroppings in, or close to, deciduous forests. Timber rattlesnakes move throughout their active season (~5 months), during which they use differing habitats for denning, basking, foraging, and birthing. Both activity and habitat use vary with time of year, sex, and reproductive status (DesMeules 1995, Spear et al. 2013). Traditional den sites, birthing areas, and routes of egress from the dens are consistently used year after year.

Denning

In northern climates, suitable overwintering sites are limited. Dens (also called hibernacula or refugia) are generally deep rock fissures or talus slopes with crevices leading to a hibernaculum below frost line. In more southern locations timber rattlesnakes can be found denning in rocky areas, mammal tunnels, root systems, and other underground retreats (Harding 2000). Snakes use the areas immediately around den sites primarily for basking at both egress and ingress. The hibernacula, with its crevices and chambers below frost line allow the rattlesnakes to overwinter as they must maintain their body temperature in the upper 30's (˚F) or higher during hibernation to survive (Furman 2007). Den sites are generally on steep slopes with rocky outcroppings for basking exposure. Shallow or well-drained soils can reduce canopy closure and therefore enhance sun exposure. In New York and places further south, den sites can be found at higher elevations, while in Vermont den sites are located on steep southwest or southeast talus slopes beneath cliffs below 215m (700 feet) in elevation. They are found in the vicinity of exposed ledges and large undeveloped or sparsely developed areas associated with woodland communities of oak (*Quercus spp.),* shagbark hickory (*Carya ovata*), and hophornbeam (*Ostrya virginiana*). The timber rattlesnake is extant only in Rutland County although scattered, unconfirmed reports without photos or specimens occasionally surface from sites in other counties.

Basking

Basking is an essential behavior for ectothermic, northern reptiles that raise their body temperatures to a point where physiological processes such as growth, digestion, healing, gestation, and parturition can occur more rapidly (Bauchot 1994). As body temperatures change from cool to warm, the snakes go from relative lethargy to being physically active and more reactive to stimuli. Basking sites are often in proximity to the den sites and are in open rocky areas with shelter rocks (often escarpment rims), or open rocky areas with good solar exposure and rock cover (talus slopes and rock slides). In Vermont, snakes were also regularly found

basking or loafing in small upland openings or clearings in woodlands, often associated with adjacent ledge or rock cover.

Foraging

Males and non-breeding females spend most of their active season in woodlands foraging for small mammals. Males tend to disperse farther and are more likely to be found in densely wooded terrain (Harding 2000). Foraging snakes of both sexes can be found in upland forest with a mixture of open and closed canopy, a mixture of deciduous and coniferous woods, and a mixture of grassy and non-grassy areas. The majority of rattlesnake telemetry locations in Vermont were in deciduous forests (46 %) mixed forest (13%) and in or adjacent to shrub/scrub wetlands (12%) (Spear et al. 2013). The deciduous forests favored by the snakes are classified as a dry oak-hickory-hop hornbeam forest community, which tend to have relatively open understories dominated by woodland sedges and other herbs (Thompson and Sorenson 2000).

Birthing

Gravid females spend the first part of the summer relatively close to the birthing sites. These birthing sites are generally typified by exposed rocky areas with cover in the form of flat rocks, exposed talus, or exposed horizontal ledge with crevices. A high percentage of Vermont's birthing areas are located within about 200 m of den sites, often on talus slopes or ledges above or below the denning portals.

Connections and Corridors between Habitats

Snakes need to be able to safely travel between the microhabitats listed above. Some of these routes in the vicinity of dens are used repeatedly over many years and by many snakes. These wooded connecting corridors are essential habitat features to provide suitable access and travel cover between important snake core areas or key habitats. As snakes disperse more widely to forage, they traverse areas that may be used less often or by fewer individuals, but such corridors are still necessary for the population to sustain itself.

HISTORICAL AND CURRENT DISTRIBUTION

Regionally

The timber rattlesnake historically ranged through much of the eastern United States (31 states) and adjacent Canada, extending from southern Ontario, southwestern Quebec and Minnesota south into northern Florida. The species has since been extirpated from Canada as well as Maine and Rhode Island. There is only a single known den remaining in New Hampshire. Presently the snake is found in 27 states from New England to northern Florida on the Atlantic Coast and from Minnesota to Texas on the western edge of its range (Martin 1992a).

Vermont

Care must be used when putting together historical and current distribution information. In Vermont, timber rattlesnakes are most often confused with milksnakes, but have been confused with other snake species as well. Misidentification occurs regularly at present and we assume it occurred historically as well. As a result, a healthy skepticism regarding rattlesnake reports is necessary.

For the Vermont Reptile and Amphibian Atlas timber rattlesnake map, a site is mapped only when one of the following conditions occurs:

- a cluster of records is received from independent observers at different times from a given area
- a record is accompanied by descriptive details that rule out all other snakes (not including shaking tails or rattling noises)
- a historical bounty was paid and recorded
- a record is from a person who has given us photos or excellent descriptions previously and is familiar with rattlesnakes
- a photograph was taken and has been verified
- a specimen is catalogued in a reputable museum

Records that do not meet one or more of these criteria are not mapped (J. Andrews, personal communication). A bullet (•) is placed only in those towns with records that were accompanied with a photograph or a specimen.

The importance of confirming records is highlighted by a story from May Pond in Barton, VT. In 1983, a letter to the editor appeared in *The Chronicle* that described an encounter with a rattlesnake at May Pond. Biologist Mark DesMeules of The Nature Conservancy investigated the report and discovered that it was a hoax perpetuated by a local landowner to dissuade developers. The hoax was again confirmed in 2003 (S. Crawford, personal communication). In 2005, a similar story appeared on a bulletin board at a Fish and Wildlife access area at the same location and this story is also considered to be a fabrication, perhaps by the same individual.

In addition to those reports that are shown on the Vermont Reptile and Amphibian Atlas map for this species, there have been additional second-hand reports from sites in the Northeast Kingdom, the Connecticut River Valley, the west face of the Green Mountains, and from the Winooski River Valley, but at this time they have not been mapped because their reliability is doubtful (DesMeules 1992, J. Andrews 2006).

Historically, there had to have been other populations connecting the scattered populations that currently are shown on Atlas maps. However, despite extensive and ongoing searches of current literature and historic state and town records, no other records have been located that meet the above criteria.

Bounties were offered for timber rattlesnakes on and off between 1894 and 1971. Rattlesnakes were briefly removed from the bounty list for two years in 1896, and again in about 1905, and added back to the list in 1921 where they remained until 1971. For the entire time, the rattlesnake bounty was one dollar (Andrews and Cillo, unpublished data, Sanford 1990). The last known bounty record in West Haven was paid in 1968.

Table 3: A summary of timber rattlesnakes turned in for bounties from Vermont from 1890 through 1971. (Andrews and Cillo, unpublished data.)

Town	*1890-1904*	*1921-1930*	*1931-1940*	*1941-1950*	*1951-1960*	*1961-1970*
Castleton	4					
Fair Haven	243			11	22	14
Benson	1-70 *	6	9	6	16-82**	10
Springfield	49					
West Haven	101	93	121	246	471	336

* Listed in the town records as fox and snake bounties.

** 66 were listed as porcupine and snake bounties, 16 were specifically snake bounties.

Although no rattlesnake bounties were found in Bristol's bounty records, The History of Bristol contains an excerpt from a letter written by the son of one of the first settlers of Bristol. He describes a story of his father, and others, killing 180 rattlesnakes in a single spring. This story occurred prior to 1840 (Harvey and Kellogg 1941). There are other historical documents that mention rattlesnakes in Bristol, including a description of a resident, Henry G. Summer, who was bitten by a rattlesnake prior to 1856.

Other notable historic sites in Vermont include the towns of Waterbury/Bolton in the Chittenden/Washington County area, Wells in Rutland County, Salisbury (Addison County), Skitchewaug (Windsor County), Bristol Cliffs (Addison County), Mt. Ascutney and Little Ascutney (Windsor County), and Bennington (Bennington County).

Denning Areas in Vermont

Currently, there are only two known denning areas remaining of the former, historic rattlesnake sites. They are both located in western Rutland County and owned by The Nature Conservancy (TNC). The habitats at these sites include ledges, open fields, talus, and oak-hophornbeam-hickory forest communities with sedge understories. The settings are in relatively sparsely developed, rural landscapes and include other rare and uncommon plant and animal communities. Several parcels on the adjacent lands are currently in municipal and state ownership and several adjoining parcels are owned by TNC. Some of the rattlesnakes denning at one Vermont site actually forage in adjacent New York habitat. Thus, management and protection activities in New York can affect the Vermont population.

LEGAL STATUS AND PROTECTION

The timber rattlesnake was added to Vermont's endangered species list in 1987. This listing reflects the state's recognition of the species' apparent decline and range reduction and was a first step in addressing these problems. Considering the last bounty was in 1971, this was a dramatic shift in public perception over a period of only 16 years. The number of states that have listed the snake as threatened or endangered demonstrates a similar shift and reflects the continued decline of the species noted in the last few decades (See Table 4). New York listed the species as threatened in 1983. New Hampshire has listed the species as endangered, and only one den site is still active in that state (M. Marchand, personal communication).

Texas, a state of numerous and well-attended rattlesnake roundups, recently listed the timber rattlesnake as a threatened species. Pennsylvania, also a state that still holds rattlesnake roundups, has designated the timber rattlesnake as a candidate for threatened or endangered status. Pennsylvania's Game Commission is assessing den sites in Pennsylvania to try to determine the current population. In addition, the state adopted a regulation to limit the size (>42") and bag limit (1) of timber rattlesnakes that can be taken under the state's legal rattlesnake hunting season (Pennsylvania Game Commission Website 2014). The exportation of goods relating to all rattlesnakes, and specifically timber rattlesnakes, prompted their proposed inclusion in the Convention on International Trade in Endangered Species (CITES) in Appendix II in 2000 (CITES 2000). Although the proposal was later withdrawn, this action reflects the changing attitudes towards rattlesnakes and the widespread concerns for their welfare. The national timber rattlesnake conservation plan (Timber Rattlesnake Conservation Action Plan, or TRCAP) (Martin et al. 2008), and an international professional society (ASIH) further describe conservation issues and status of rattlesnakes (Mushinsky et al. 2006).

Table 4: Status of the timber rattlesnake in New England and surrounding areas.

State or Province	
Connecticut	Endangered - designated in 1992
Delaware	No records of rattlesnakes inhabiting Delaware
Illinois	Threatened
Maine	Extirpated - existed until middle of nineteenth century
Massachusetts	Endangered – first law to protect snakes in 1979
New Hampshire	Endangered – designated in 1987
New Jersey	Endangered – designated in 1979
New York	Threatened - designated 1983, bounty ended in 1971
Ohio	Endangered
Ontario	Extirpated – last reported from Ontario was in 1941
Pennsylvania	Candidate to be listed as threatened, current bag limit of one
Rhode Island	Extirpated – last reports from 1972
Vermont	Endangered - designated in 1987
Virginia	Endangered - designated in 1992

Breisch 1992, Brown 1988, Brown 1992, Casper and Hay 1997, Mitchell 1994, Norton 1929, Palmer 1946, Raithel 1992, Seburn and Seburn 2005.

THREATS and LIMITING FACTORS

Habitat Losses and Degradation

In addition to the traditional threats to species from habitat loss and degradation, snake fungal disease and persecution are the principle threats facing timber rattlesnakes. According to the Environmental Protection Agency (EPA), between 1982 and 1992 Vermont lost 6,500 acres (~ 10 sq. miles) to development each year and that rate was accelerating (EPA 1999). While most commercial development is concentrated away from known rattlesnake habitat, there has been an increase in camps and second homes in the rural areas near Vermont's dens. These types of development can have a negative impact on snakes in many ways, including loss of habitat,

habitat fragmentation, population isolation, increases in human/snake interactions, higher traffic levels/road mortality, and heightened off-road/ATV use. All these factors result in a loss of habitat permeability (ability for rattlesnakes to move through safely) or within populations and between populations (connectivity), therefore limiting genetic exchange. For the long-term success of a population, genetic diversity needs to be maintained. Small populations may be at risk of genetic drift, bottleneck effects, and inbreeding depression, resulting in a loss of genetic diversity (Russell 1994) genetic diseases and disorders (Russell 1994, Weyrauch and Grubb 2006) and increased likelihood of extinction (Weyrauch and Grubb 2006).

Roads and Road Mortality

Roads can attract snakes; the smooth sunny pavement or gravel is similar to the basking rocks or ledges around their den sites. In addition to the direct mortality caused by cars, logging trucks, and ATVs, road building can also lead to an increase in human/snake interactions, and fragmentation of the forest and the snake's habitat. Roads can act as significant barriers for dispersal or for snakes traveling for the purpose of mate searching or foraging (Bonnet et al. 1999), thereby having a direct impact on their ability to find and mate with snakes from other populations, or to access critical habitats. In a New York study of road impacts on rattlesnake population structure, gene flow and connectivity, Clark et al.(2010) found that even minor roads (3,000 vehicles/day) resulted in decreased gene flow/connectivity and increased population isolation when compared with den sites on the same side of the road.

Vermont researchers found apparent rattler avoidance of a heavily traveled, adjacent road (5,300 vehicles/data - VTrans data) as well as evidence of the road presenting a significant barrier to snake movement/dispersal. None of 22 telemetered animals attempted to cross this adjacent road during the course of the two-year study (Spear et al. 2013). When calculating the probability of mortality for timber rattlesnake, racers, and eastern ratsnakes, Andrews and Gibbons (2005) found that the probability for mortality was highest for a timber rattlesnake. They estimated that timber rattlesnakes crossing roads would suffer 80% mortality rate on roads with traffic volume of 3,000 vehicles/day and a mortality rate close to 100% on roads with traffic volumes >9,000 vehicles/day. Since 2001, Vermont has documented only 10 dead rattlesnakes found on this particular road, demonstrating this highly fragmenting landscape feature and the unlikely prospect of dispersing snakes successfully negotiating road crossings even with current traffic levels.

Another study evaluated differences between snake species in their willingness and time taken to cross roads. Timber rattlesnakes were more likely to "freeze" before and while a car passed, lengthening their time on the road and increasing their chances of getting hit (Andrews and Gibbons 2005). As a relatively slower moving species, timber rattlesnakes are less likely to successfully cross the road as compared to a faster species such as the North American racer. Roads are detrimental to all snake species, but their effects may be greater on the timber rattlesnake.

Disease

In 2012, the newly emerging skin fungus *Ophidiomyces ophiodiicola* (*Oo*) was detected and subsequently confirmed by PCR ID in rattlesnakes from one population in Vermont. A number of snakes in this study displayed troubling symptoms of facial blisters and/or skin lesions associated with this disease commonly called Snake Fungal Disease (SFD). A few cases of mortality apparently associated with this disease were also observed. In 2014, *Oo* was also confirmed in Vermont's second rattlesnake population. The documented presence of this fungus in the state is a very disconcerting finding as *Ophidiomyces ophiodiicola* appears to act as a primary pathogen on snakes, rather than an opportunist, with potentially lethal effects.

In the last several years, the threat of SFD and its potential impact on snake populations has become an issue of serious concern and alarm, particularly in the East. Rattlesnake populations experiencing this fungus in New Hampshire and Massachusetts have been severely impacted. In Illinois, the mortality rate to date of massasauga rattlesnakes afflicted with *Oo* has been close to 100% (Allender et al. 2011). In addition, cases of this debilitating fungus have surfaced in a dozen eastern states in 10 different snake species in the last several years. Currently, it is not known how the disease may be spread.

In an attempt to address this issue, an eastern regional team of experts including state wildlife biologists, university scientists, veterinary pathologists and clinicians are collaborating to determine how best to gather additional, vital information from involved snake populations, along with the critical funding sources needed to assess this extremely serious threat to free-ranging snakes. Vermont will continue disease surveillance/testing by participating in a regional study involving 10 eastern states titled "Conserving Snake Species of Greatest Conservation Need [SGCN] Threatened by an Emerging Fungal Skin Disease". The stated objective of this competitive State Wildlife Grant (SWG) funded study is: 'To assess the causes and conservation significance of an emerging fungal skin disease in SGCN snakes in the eastern U.S., and develop a response.' The disease may prove to have significant negative impacts related to Vermont's endangered rattlesnake population as it has the potential to overwhelm recovery efforts or other conservation actions on its behalf.

W.S. Brown recalled observing a so-called "listless" timber rattlesnake a number of years ago at one Vermont denning area (W. Brown personal communication) and he has reported the incidence of this malady called the "listless syndrome" in his long-term study of a nearby New York population (Brown 2008). No other listless snakes have been reported in subsequent years in Vermont.

There are other diseases that have been known to affect captive populations of Crotalus. Paramyxovirus is a fatal virus that has been known to infect captive snakes, including rattlesnakes, living in close proximity to each other (Mackessey 2005). The first outbreak in a North American collection was recorded in 1979 with subsequent collections having outbreaks since that time (Jacobson and Gaskin 1992). Ratsnakes have been known to harbor a similar virus, but transmission between species is not known.

A parasite, *Porocephalus crotali* is known to mature in the lungs of snakes. The worm is passed from snake to snake using an intermediate rodent host (Goater and Goater, n.d). However, there have been no known cases of either of these diseases in Vermont's population,

Human Persecution/Mortality

Many people have a fear of timber rattlesnakes (and other snakes) which is out of proportion to the actual threat the animals pose and thus, many snakes are killed when encountered, regardless of the threat. Negative human attitudes towards rattlesnakes can impact a population on a large scale, (e.g. rattlesnake roundups), and on a smaller scale (e.g. reckless killing done out of fear or ignorance). In the small, endangered populations in the Northeast, indiscriminate killing/removal of even a single adult female can result in significant consequences to the population. (Brown et al. 1982)

One of the major challenges is to remove some of the human fear and disdain associated with these reptiles. Adopting W. Brown's program in New York, Vermont has successfully implemented a "rattlesnake response program" to safely remove errant snakes from residential dooryards, driveways, etc. This free service has not only saved valuable animals, but at the same time provides outreach opportunities to enhance landowner education, awareness and understanding of this typically misunderstood species.

Other Human Disturbances and Direct Mortality

Commercial Collecting

The threat from direct human collection is a significant one to Vermont rattlesnakes. M. DesMeules describes an incident that occurred in 1992 where two snake collectors were confronted and photographed in a posted Nature Conservancy Preserve (DesMeules 2005). Alcott Smith also noted human activity at the dens he monitored.

Information freely available on the internet could allow almost anyone access to specifics regarding den locations or recent sightings. An interested person could potentially purchase part of or an entire timber rattlesnake over the internet with relative ease. In addition one could purchase a map, download a report, and/or take part in a blog involving valuable/exotic species. It is not difficult to locate a timber rattlesnake specimen for purchase. A five-minute internet search for "timber rattlesnake for sale" yielded an offer to purchase a timber rattlesnake (western variety for $50.00). There is also a great deal of rattlesnake paraphernalia for sale at numerous on-line auction sites. It is possible to buy rattlesnake bone necklaces, fangs, skins, rattlesnake skin boots, and, for the uninformed, rattlesnake "eggs." Although these kinds of items aren't limited to timber rattlesnakes, this species is threatened by the existence of this market which is very difficult to control and monitor.

Easy access to internet information is a more recent threat, but one that should be considered when discussing/disseminating public outreach efforts or research findings. Increased knowledge of den sites has led to more frequent disturbances of these sites and possible takings. Brown (1993) states that not revealing the localities of the den sites are an important aspect of timber rattlesnake conservation.

A notorious poacher, Rudy "Cobra King" Komarek, has had a detrimental impact on the populations of timber rattlesnakes in New York and Massachusetts (Brown et al. 1994). Komarek was infamous for illegally collecting and selling snakes. It's been estimated that over a 45-year period, Komarek was directly responsible for the illegal take of at least 2,940 timber rattlesnakes in New York alone (Brown et al. 1994). This poacher had been quoted as admitting to taking about 9,000 timber rattlesnakes from the wild in the past five decades. In the past decade he also attempted to sell maps to many den sites, including the dens sites in Vermont (Naik 1994, Smith 2004). Although Komarek died in March, 2008, the threat of illegal take continues as demonstrated by the multiple arrests resulting from "Operation Shellshock", a successful undercover law enforcement effort by New York DEC in 2009 to disrupt the lucrative illegal trade in reptiles.

Human Disturbance

Even with the best intentions, humans can unwittingly disturb the snakes and have an impact. A study of eastern massasauga rattlesnakes *(Sistrurus catenatus)* in Ontario compared visibility of snakes with a high level of human disturbance to snakes with a low level of human disturbance. The researchers found that as disturbance increased, gravid females became less visible, while males and non-gravid females did not change their behavior (Parent and Weatherhead 2000). However, the researchers did not find a difference between the two groups in terms of the snakes' condition, growth rate, or gravid females' brood size (Parent and Weatherhead 2000). Weatherhead and Demers (2004) found that female eastern ratsnakes equipped with radio transmitters were able to reproduce successfully although their clutches were lighter relative to their body mass compared to females not equipped with transmitters. A North American racer in Vermont equipped with a transmitter died within the first year of a study of this species in 2007. It's possible that the research project may have contributed to a change in behavior and the snake's ultimate death (E. Talmage, personal communication).

Brown (1993) found disturbance of certain rocks favored by timber rattlesnakes could change snakes' normal routines. After a few disturbances it is likely a snake will flee more quickly than before, or it will abandon a rock altogether (Brown 1993). More recently, Brown (2007) has described long-term data documenting what he calls the "intimidation effect" in timber rattlesnakes.

Predation

Few species take adult rattlesnakes as prey. Neonates and juveniles are more vulnerable due to their small size and lack of experience (Rubio 1998). Predators that might attempt to kill rattlesnakes include: raccoon (*Procyon lotor)*, Virginia opossum (*Didelphis virginiana*), striped skunk (*Mephitis mephitis*), domestic dog (*Canis familiaris*), red fox (*Vulpes vulpes*), weasels (*Mustela* spp.), North American racer, eastern coyote (*Canis latrans*), northern raven (*Corvus corax*), American crow (*Corvus brachyrhynchos*), blue jay (*Cyanocitta cristata*), eagles (subfamily Buteoninae), hawks (Accipitridae), and owls (Tytonidae and Strigidae) (Ernst and Ernst 2003, Rubio 1998).

CURRENT MONITORING AND MANAGEMENT IN VERMONT

Monitoring

Beginning in 2011, the Vermont Fish and Wildlife Department (VFWD), along with conservation partners, The Orianne Society and The Nature Conservancy, began an intensive field study and investigation on the ecology and status of the rattlesnake population in Vermont. For two years, rattlesnake activity, home range, movement behavior, health status, genetic diversity and demographics were documented at extant dens and surrounding areas. We captured and marked 144 individual rattlesnakes at our largest den site and radiotelemetrically monitored the movements of a combined seventeen males, three non-pregnant females and two pregnant females from May through October of 2011 and 2012. Ultimately, the study resulted in 206 snake capture events and 672 GPS telemetry locations. Field data generated from this investigation was extensive and heavily utilized to inform this recovery planning process. (See Figure 1, Table 5, and Appendix Tables 6, 7; Spear et al. 2013).

Formal monitoring and disease surveillance efforts are planned to continue through 2015-16 as Vermont participates in an eastern US regional investigation into SFD disease/health status of timber rattlesnakes and other snake species.

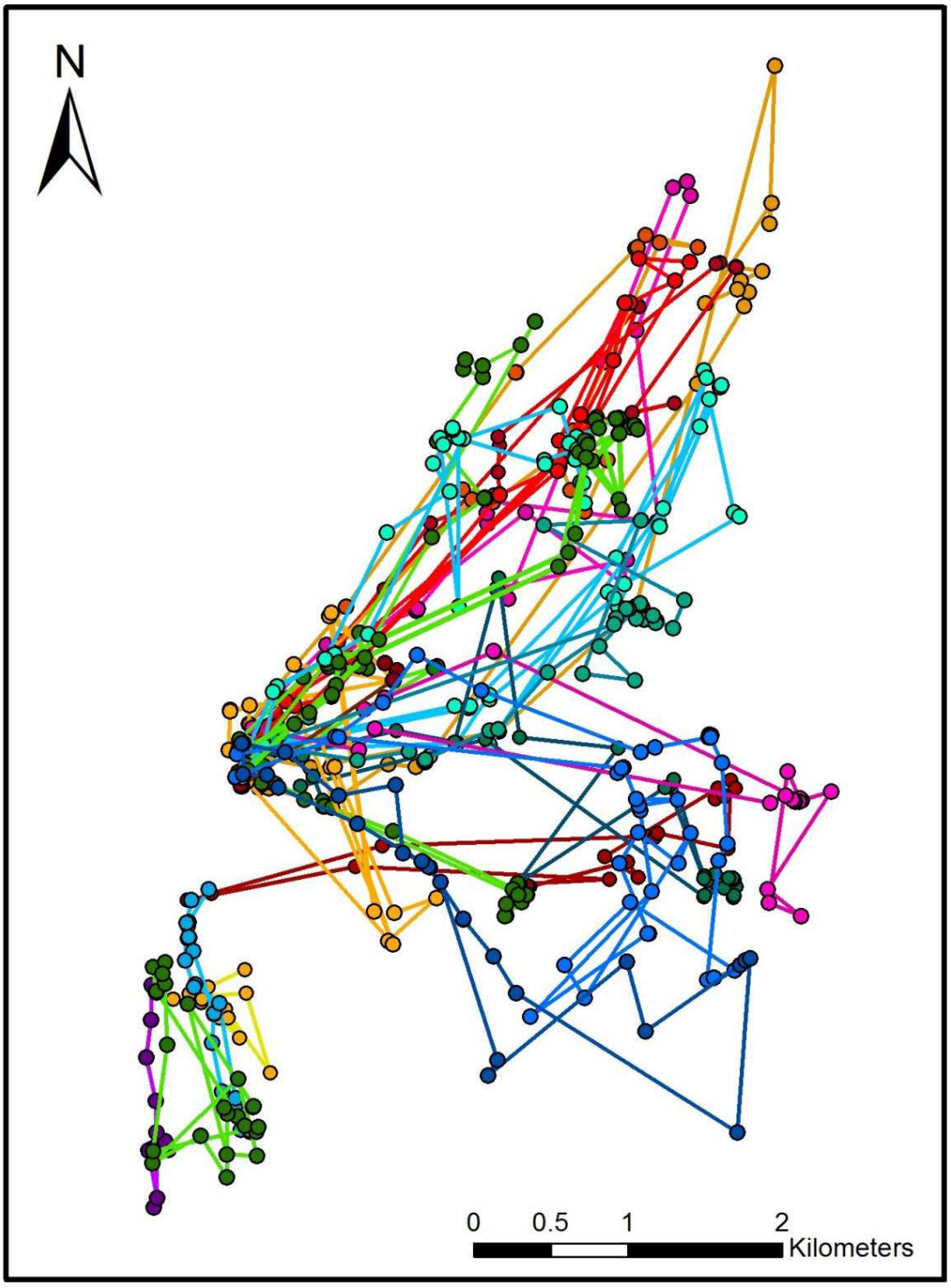

Figure 1. Schematic of movement patterns for 22 telemetered timber rattlesnakes (*Crotalus horridus*) monitored with radio telemetry in west-central Vermont in 2011 and 2012.

Effective Population Size

Effective population size (Ne) can be defined as "the size of an ideal population (i.e., one that meets all the Hardy-Weinberg assumptions) that would lose heterozygosity at a rate equal to that of the observed population." (Univ. of Wyo. Lect. 07). Stengle et al.(unpublished) estimated effective population size at one Vermont den site (77 tissue samples) using two different measures (with confidence intervals) is presented below:

Program	Ne Estimate	CI - Lower	CI - Upper
ONeSAMP	32.80	24.07	52.99
LDNe	78.70	42.40	226.00

Franklin (1980) and Mace et al. (2008) state that maintaining an effective population size of at least 50 is necessary to avoid deleterious inbreeding depression. This particular threshold appears to have been met for this Vermont population using the LDNe estimate, which may be the more accurate method. (A. Whitely, unpublished) It should be emphasized that an estimate of effective population size is not readily comparable to demographic population size.

Genetic Diversity

Stengle et al. (unpublished) also conducted genetic analysis of the same Vermont population yielding the following results:

Table 5. Genetic summary statistics for a Vermont population (n = 77) of timber rattlesnakes (*Crotalus horridus*), with departure from Hardy-Weinberg proportions (F_{IS}), expected heterozygosity (H_e), observed heterozygosity (H_O), and number of alleles present (A).

Locus	F_{IS}	H_e	H_o	A
CwB23	0.184	0.827	0.676	7
Scu26	0.000	0.632	0.632	4
CwD15	-0.045	0.124	0.130	3
Scu05	0.006	0.335	0.333	4
7-87	-0.109	0.187	0.208	2
CwC24	-0.057	0.826	0.873	13
Scu01	-0.264	0.381	0.481	2
Scu07	N/A	0.000	0.000	1
5-183	N/A	0.000	0.000	1
7-144	0.010	0.651	0.645	4
7-150	N/A	0.000	0.000	1
CwA29	-0.184	0.512	0.605	3
Scu11	0.041	0.737	0.707	4
Average	-0.015	0.401	0.407	3.769

The relatively low level of genetic diversity (heterozygosity = 0.4, number of alleles = 3.8) observed by Stengle et al. (unpublished) at this den complex is consistent with an isolated population that is subject to genetic drift and resulting reduced genetic diversity. Although the numbers are not completely comparable because different loci were used, Clark et al. (2010) found higher levels of heterozygosity (range 0.55-0.66) and number of alleles (3.82-6.21) at dens in New York. However, at an isolated den in New Hampshire, genetic diversity was lower than this Vermont complex, with only 2 alleles per locus (Clark et al. 2011). The NH den has exhibited evidence of strong inbreeding depression, which to this point has not been detected in Vermont. The fact that the inbreeding coefficient (FIS) is near zero suggests that currently there is approximately random mating in the population and not extensive mating among related snakes. The loss of diversity likely has occurred due to the general decline of rattlesnakes across Vermont and the isolated nature of the den, but the population size appears to be large enough to be preventing inbreeding depression, at least for the moment.

It appears very unlikely that there is successful genetic exchange between Vermont's extant rattlesnake populations. It may be more likely that occasional exchange may occur between a New York den site and Vermont's most western Rutland County den. Hopefully, additional genetic analysis currently underway (A. Stengle) can provide additional, empirical data on this issue of dispersal among these den sites. In any case, genetic exchange of rattlesnake populations will be an essential consideration for future recovery efforts.

Population Size Indices

According to recommendations by A. Smith, W. H. Martin, and W. S. Brown **(**personal communications), a useful index to estimate the demographic population size of a rattlesnake population from a given denning area is the annual, one-day high count of rattlesnakes of all ages seen emerging from and basking in the denning area. They estimate this count ranges from 10% of the total population on an average day and up to 30% of the total population on an exceptional day. All three experienced observers support an index of 25% for a detectability estimate, thus using a conversion factor of four for a rough population estimate. This assumes that on the best spring observation days in any year, an experienced observer familiar with appropriate timing, locations, and weather conditions for emergence could detect roughly 25% of the snakes actually present (A. Smith, W. Martin, and W. Brown, personal communications; NatureServe 2010). To minimize the impact of one or two years with poor detection results, we recommend using a running average of the last five years highest-single-day counts to calculate the population index. This average count could be multiplied by four to generate a rough estimate of the total population size at each denning area.

W. Martin (unpublished data) also utilizes a population index derived from extrapolation of observations of the number of adult/gravid females documented over time. Based on years of observations and documentation of dozens of central Appalachian rattlesnake sites, Martin estimates adult rattlesnakes ($\geq$33 inches) comprise approximately 40% of the total number of animals in the population and adult females comprise roughly 16% of the population.

Utilizing these population indices, Vermont demographic study data yield a rough estimate of the 2012 rattlesnake population in the range of several hundred animals, statewide. Vermont's total

rattlesnake population is comprised of two discrete populations, located approximately seven miles apart. One population consists of a den complex of several dens in close proximity (<.5 miles apart), and the second population consists of two den sites, located between .5 miles and 3.5 miles apart. (The amount and frequency of genetic exchange between these two populations is currently unknown, but assumed to be very minimal to non-existent due to the long distance and high volume of traffic on some roads between them). It also should be stressed that the current impact of snake fungal disease is unknown but is a significant threat potentially affecting extant populations.

(See below for definition of terms utilized in this document)

Den or hibernacula – habitually used, communal overwintering site for snakes

Den complex – two or more den sites with genetic exchange, located less than .5 miles apart

Population – all the individuals of one species in a given geographic area.

Metapopulation – group of spatially separated dens or den complexes (>.5 - < 3.5 miles apart) with genetic exchange

Isolated den - a single den located greater than 3.5 miles away from another den

Snake Management Unit (SMU) – area containing active den site(s) with surrounding suitable habitat of sufficient size and connectivity to support metapopulation structure. Minimum size of the SMU is > 5,500 acres of suitable snake habitat, not containing fragmenting/barrier roads (>3,000-5,000 vehicles/day).

Conserved habitat – habitat protected from development via ownership or easement

Past and Future Land Protection Efforts

Beginning in 1981, TNC has worked very diligently to secure and conserve Vermont extant denning areas and surrounding rattlesnake range. With the help of the Vermont Housing and Conservation Board and other private funding sources, these efforts have come to fruition as TNC has gradually conserved several Vermont den sites along with thousands of acres of adjacent rattlesnake habitat. Applying Vermont's observed average male rattlesnake displacement distance of 2.2 miles and incorporating public lands, approximately 75% of the buffer area around one den complex is conserved and some 50% of the second. Although protection efforts should continue in this regard, the amount of rattlesnake habitat conserved to date is an enviable achievement. Of the 672 telemetry locations obtained in the 2011-12 study, 53% (357) occurred on protected lands (Spear et al. 2013). The surrounding lands at each site are also ecologically valuable property. One represents a southern calcareous summit community along with its companion community, the calcareous talus forest/woodland (Parren, 1998). The area also supports a diversity of rare plants including Hooker's orchid (*Platanthera hookeri*), hairy beardtongue (*Penstemon hirsutus*), the palmate-leaved violet (*Viola palmustum*), and green

rock-cress (*Arabis missourifensis*) (Thompson 1991). Other rare reptiles and amphibians at one or more of the sites include eastern ratsnake and four-toed salamander (*Hemidactylium scutatum*) and Vermont's only lizard, the five-lined skink (*Plestiodon fasciatus*).

The Vermont study also provided valuable snake habitat use information as the basis to develop a GIS layer identifying important lands used by rattlesnakes. This information will be used to guide and prioritize future land protection efforts.

Active Forest Management

The Vermont Fish and Wildlife Department in concert with the Vermont Department of Forests, Parks, and Recreation (VFPR), have carefully conducted several active logging operations on public lands in rattlesnake range specifically to improve habitats and enhance vegetative conditions for rattlesnakes. These enhancements have included creating clearings and forest openings for foraging/basking, enhancing mast production, "daylighting" forest/ledge basking areas, creating brush piles for cover and foraging opportunities as well as enhancing availability of understory structure/woody debris. Similar "daylighting" activities have also been conducted on TNC lands at some traditional basking and gestation areas. Throughout the duration of Vermont's telemetry study, we observed dozens of telemetry locations where rattlesnakes were specifically utilizing these enhanced, managed habitats for their various activities. Due to the success of these operations, these kinds of habitat enhancements will continue when appropriate on state lands in rattlesnake range.

Law Enforcement and Permitting

Currently, the timber rattlesnake is fully protected and listed as endangered under Vermont Endangered Species Law (10VSA T10 Sect 5401-5408), and international trade is restricted (CITES 2000). All New England states and New York have given the timber rattlesnake state protection. The VFWD wardens are aware of the significance of the species and its protected status. Unauthorized den site visits, collection, and harassment have been known to occur, thus den site access is restricted. The local warden knows the location of the denning areas, and has actively participated in rattlesnake removal training and enforcement activities.

Outreach and Education

VFWD and TNC have organized talks, slide shows, and an occasional field trip to educate the public about rattlesnakes as well as other unusual reptiles in the area (e.g., eastern ratsnake, common five-lined skink (*Plestiodon fasciatus*), and eastern ribbonsnake (*Thamnophis sauritus*).

Jim Andrews works with The University of Vermont Division of Continuing Education and the Department of Wildlife and Fisheries Biology to educate undergraduate, graduate, and continuing education students about snakes, including timber rattlesnakes, in Vermont. He also speaks regularly about Vermont snakes to a wide variety of residents around the state.

Most recently, other education venues have been offered by VFWD. These include television coverage of rattlesnake field research activities featured on segments of Vermont Public Television's "Vermont Outdoor Journal" and, Vermont Public Radio's "Vermont Edition" talk show, etc. Other media venues on rattlesnakes include the VFWD website as well as traditional

newspaper and magazine articles. The Orianne Society staff has also presented several conference presentations on Vermont rattlesnake research.

The "Rattlesnake Response Program" began in 2004 and has been implemented every year since. This was a cooperative effort of TNC and VFWD to protect both snakes and residents. The purpose of the program is to safely remove rattlesnakes that are found close to human residence as well as to educate local landowners about timber rattlesnakes. In March, 2004, notification letters were sent to residents of West Haven, Fair Haven, Benson, and Castleton who own property within the expected traveling range of timber rattlesnakes, explaining the program's free service. The letter also invited members of the public to an educational talk (90 people attended) and gave a detailed description of the snake. The Rattlesnake Response Program provided a calling list of local, trained volunteers and staff to move rattlesnakes found in high-use areas. Local residents who encountered rattlesnakes around their homes, garages, barns, or yards were encouraged to call on appropriately permitted "rattlesnake responders" to safely move the snake away from their property, thereby reducing the number of rattlesnakes killed out of fear, maintaining landowner support, and cutting down the number of future interactions. From 2006-2013, refrigerator magnets highlighting the program were distributed so phone numbers were readily available to local residents. Since its inception, this program has demonstrated significant success in safely relocating errant, displaced snakes, protecting public safety, and equally as important, enhancing adult survival. For these reasons this key program will be continued.

VFWD staff also assisted VFPR with the development and distribution of 'snake education kits' for their state park interpreter program. Included in each kit are snake sheds, skeleton replicas, species range map images and egg replicas from a variety of species. The kit also includes the narratives for the "Snakes of Vermont" education packet to help park interpreters and program participants learn about specific species.

GOALS, OBJECTIVES AND ACTIONS FOR RECOVERY

Recovery Goals

The recovery goals for Vermont populations of timber rattlesnakes are to:

1. Secure and enhance known populations of the timber rattlesnake to levels that can safely provide for long-term population stability within the historic range of rattlesnakes in Vermont.
2. Provide a sufficient quantity of high quality, conserved habitat to support these populations.
3. Remove the timber rattlesnake from the Vermont list of threatened and endangered species when its long-term persistence in the wild has been secured.

Recovery Objectives

Criteria for Downlisting from Endangered to Threatened

All of the following criteria must be met:

1) At least three functioning metapopulations that are conserved. Dens (or den complexes) within each metapopulation must occur 0.5 miles to 3.5 miles apart, in suitable habitat.

a. Each metapopulation must consist of a minimum of >50 adult females (corresponds to 120 breeding adults/ 300 total animals, excluding juveniles < 1 yr.) As Vermont lies at the northern extent of rattlesnake range which may delay sexual maturity, breeding adults are defined as those $\geq$ 35 inches in length. (Martin, personal communication)

b. At least one of the three metapopulations must occur in historic Vermont rattlesnake range outside of Rutland County. (Bennington County, mid-upper Champlain Valley or lower Connecticut River Valley).

2) A statewide total of >200 adult females* (corresponds to 500 breeding adults/1250 total) which persists over a 10-yr. period.

* *Note* - An isolated den must consist of a minimum of 8-10 adult females (50-60 total animals) in order to be considered recoverable (Martin 1992a) and added to the statewide total number of animals.

3) Sufficient levels of successful breeding/recruitment must be achieved and sustained combined with adequate age class diversity. Levels of successful breeding will be considered met if the running 5-year average number of gravid females and/or litters approximates 25% of the number of adult females. Adequate age class diversity approximates 30% young-of-year/30% juveniles/40% adults. These must persist over a 10-year period.

4. Establishment of Snake Management Unit(s) of surrounding suitable habitat of sufficient size and connectivity to support metapopulation structure.

a. Each SMU must be >75% conserved.

Criteria for Delisting from Threatened

In addition to all of the downlisting criteria above, the following criteria must also be met:

1) At least four functioning metapopulations (as defined in downlisting criteria) that are conserved.

a. At least two metapopulations must occur in historic VT rattlesnake range outside of Rutland County. (All metapopulation criteria as defined above must apply.)

2) A statewide total of >400 adult females (corresponds to 1000 breeding adults/2500 total animals) which persists over 10-year period.

Justification for Objectives

Timber rattlesnakes are at risk in Vermont (and in New England) due to the following factors:

Vermont rattlesnakes are a K-selected species with late maturation, low reproductive rates and recruitment, coupled with a very challenging, harsh northern climate. Male and female timber rattlesnakes become sexually mature at different ages (5.3 and 8.3 years respectively) with only a few reproductive events (once every four to five years) expected in the adult female's lifetime (Aldridge and Brown 1995, Brown 1991). These demographic parameters are reflected in our downlisting and delisting criteria.

Historical den sites have been lost in former range and their habitat is significantly degraded and fragmented, concentrating remaining populations in only two known sites in a small geographic area. The rattlesnake has borne the brunt of a culture of persecution as the species is feared, and lacks public acceptance and understanding.

While our knowledge of Vermont's rattlesnake populations is improving, current scientific understanding of our rattlesnake population demographics, productivity, mortality, recruitment, and locations of critical habitats is incomplete.

● The requirement for multiple, functioning metapopulations in historic range beyond Rutland County for down/ delisting ensures redundancy across the landscape to protect against deleterious impacts of stochastic, environmental/demographic events on local populations and provide assurance against the elimination of the species in the state.

● The distances between dens (or complexes) to assume genetic exchange (<3.5 mi.) are based on the average displacement distance of 2.2 miles (in suitable habitat) for Vermont telemetered male snakes and 1.4 miles for females. Brown (1993) documented mean migratory distances of 2.5 miles and 1.3 miles for males and females respectively.

● Connectivity facilitated by functional travel corridors, unfragmented by major roads (>3000 to 5000 vehicles /day) between dens is necessary to maintain free genetic exchange and maintain metapopulation viability. (Clark 2010, Spear et al. 2013)

● The extant rattlesnake populations in Vermont occur with access to 5,500 + acres of quality (largely forested) habitat unfragmented by major roads. Currently, each of these occupied snake management units are greater than 50% conserved (but less than the goal of >75%).

● Extensive distances between metapopulations, coupled with the hurdles of numerous fragmenting roads prevent gene-flow and thus require that each metapopulation must contain a minimum, sustainable population greater than 50 adult females (120 breeding adults).

● A statewide total of >200 (i.e., downlisting) and >400 (i.e., delisting) adult females is approximately four to seven times the current estimated adult female population (50-60) respectively. These threshold figures correspond to 500 and 1000 breeding adults, and a corresponding total population of 1250 and 2500 animals respectively. According to Frankel and Soule (1981) the minimum population size to sustain a population over the long-term has been estimated to be about 500 breeding adults. Primack's (1993) conservation biology rule-of-thumb states a population size of 50 individuals as the minimum to prevent population extirpation in the short term, and 500 individuals needed to insure long-term population persistence. To avoid deleterious inbreeding Mace et al. (2008) recommended that minimum effective population sizes of at least 50 be maintained, corresponding to an absolute minimum population of 500 individuals. Pennsylvania has adopted an IUCN population threshold figure of 2500 animals as one of its numerous regional, population and demographic criteria for consideration of listing rattlesnakes in their state (C. Urban, personal communication).

● Monitoring of reproductive females combined with number/sizes of litters averaged over five-year periods will enable detection of declines in reproductive success and/or adult female population declines, precluding down/de-listing.

● Population trends require a 10-year duration to limit interpretations of short-term fluctuations from a variety of environmental conditions and demographic factors. By sampling the populations over 10 years, patterns of high and low fluctuations are better understood and more reliable trends revealed.

RECOVERY ACTIONS

As rattlesnakes are a long-lived, K-selected species with low reproductive output, strategies for recovery should include efforts to monitor and protect adult and sub-adult populations. It's also necessary to conserve and protect critical snake habitats including denning and birthing areas, basking and foraging habitats as well as movement corridors. Introduction of novel alleles or other forms of genetic management may become necessary in certain situations to maintain gene flow and genetic diversity. Strategies that include public outreach will be essential to increase awareness, acceptance, respect and appreciation for this species through modified behavior and community involvement in conservation where appropriate. Specific actions are described below with the highest priority actions labeled accordingly.

MONITORING AND MANAGEMENT

Monitor Populations and Determine Population Characteristics

Minimally disruptive monitoring protocols should be used in order to assess population stability and determine the success or failure of conservation efforts. Research methods should be evaluated based on the potential threats to the population and the conservation value of the potential information gained.

● (**Highest**) Consistently and regularly utilize the population indices described above while monitoring sites to determine the numbers of snakes/gravid females/litters observed by experienced observers during optimum weather conditions, at appropriate times and productive locations. Ideally, the population size, age-class distribution, health status, female reproductive status, annual recruitment, and sex ratio of Vermont populations should be determined and monitored using methods that generate statistically reliable data. Given economic and biological realities however, this likely will not be feasible over the long-term and will require a more efficient strategy. Consequently, it may be necessary to focus on determining the number of adult and gravid females, which in turn can be used to extrapolate an estimated size of the total population. Mid to late July is an efficient time to monitor gravid female gestation sites as most other snakes will be off foraging. Demographic information should be averaged over five-year periods to smooth out fluctuations and discern trends. Monitoring the status of the adult female population will indicate progress towards meeting the statewide down/delisting objectives of 200 and 400 respectively.

● (**Highest)** Continue to maintain vigilance in SFD surveillance/monitoring and testing as per regional protocols to keep appraised of the population's welfare and health status. Snake fungal disease is potentially the most immediate and critical threat to Vermont's rattlesnake population as the disease has the potential to overwhelm all other recovery and conservation efforts on its behalf. Evidence of precipitous population declines may warrant swift measures to augment/support populations if necessary (via headstarting, augmentation.) Share/coordinate information/research with state/regional partners/veterinary pathologists to increase knowledge of SFD, its impacts and potential treatment.

● Continue to opportunistically obtain and archive genetic samples as necessary to inform investigations of genetic exchange and variability. Conduct periodic genetic assessment of Vermont populations to inform genetic relationships among dens and metapopulations as well as levels of inbreeding.

● Evaluate management techniques to facilitate gene-flow (e.g., translocating appropriate individuals, captive rearing/headstarting) and/or to augment vulnerable populations as a possible future conservation tool. Consider the possibility of re-introductions to historic range after evaluating potential, appropriate sites and leading essential public involvement efforts to garner informed public consent.

● Conduct systematic, repeated visual surveys in appropriate times and weather conditions to monitor and document snake occurrences, locations, habitat use and population data at known sites. Observed snakes will have locations confirmed/mapped via GPS and estimates of sex/age noted. Employ pit-tagging or other forms of snake identification (e.g., rattle painting) on select individuals for long term information. Employ remote sensing cameras when and where appropriate to enhance monitoring efforts.

● Continue to survey for additional hibernacula, birthing/basking areas and ingress and egress routes.

● Survey additional potential areas of timber rattlesnake distribution during key time periods based on recent (last 25 years) sighting records. A partial list of sites to be checked include: *Skitchewaug* (Springfield, Windsor County) *Little Ascutney* (Weathersfield, Windsor County) *Rattlesnake Point* (Salisbury, Addison County) *Bristol Cliffs* (Bristol, Addison County) *Snake Mountain* (Addison, Addison County*) Glen Lake area* **(**Benson, Castleton**,** Fair Haven, Rutland County**).**

● Follow-up on credible, quality reports of sightings of rattlesnakes, particularly those in historic range.

● Recover dead specimens to document locations, sex, estimated age, health status, etc. and obtain genetic samples.

● Consider population viability analysis/modeling to assess and refine risks to metapopulations.

LAND CONSERVATION/CONNECTIVITY/HABITAT MANAGEMENT

Land Conservation/Connectivity

The populations of timber rattlesnakes that currently exist in Vermont are found where there are large tracts of undeveloped forestland near denning areas. Populations at other historic sites (Andrews 2006) that became more developed, more fragmented, or more isolated from other populations have apparently disappeared (e.g., Rattlesnake Point, Bristol Cliffs, Skitchewaug). Increased development, increased recreational use, and increased traffic increases the possibility of accidental or purposeful snake mortality and limits opportunities for gene exchange, recolonization, or dispersal. Thus, long term population health and genetic diversity is dependent upon habitat permeability and connectivity provided by movement corridors in a largely undeveloped or rural landscape.

● (**Highest**) Develop, prioritize and pursue a land acquisition/easement plan to secure and conserve vital denning habitats and suitable surrounding habitat in 5,500+ acre Snake Management Units to support the species. Identification and targeting of critical habitat is essential for success and cost effectiveness. Spear et al. (2013) documented lands most frequently utilized for one rattlesnake population in Vermont specifically for this purpose of guiding/prioritizing habitat conservation. The Vermont Agency of Natural Resources and TNC

have jointly worked for nearly two decades in this manner to conserve many of these critical habitat pieces and have accomplished a great deal in this effort. Their work should be commended and continued efforts supported. Identify, protect and foster habitat corridors that facilitate movement to accommodate snake dispersal and movement between den sites, foraging areas, birthing sites, ingress and egress routes. Avoid inclusion of fragmenting roads in Snake Management Units and/or consider designing effective structures/culverts for safe passage under roads where snakes are known to cross.

● Continue the progressive, on-going collaborative efforts between the VFWD and Vermont Agency of Transportation (VTrans). These two agencies can gather reports of road-killed specimens, road crossing, and road basking areas, and help facilitate the research, planning, implementation, and monitoring of road crossing structures and barriers when warranted. Both agencies should continue to review highway design and maintenance projects in appropriate habitat within the known or expected range of our populations in an effort to minimize impacts and facilitate safe animal travel and dispersal. Continue current VTrans employee field training classes to enhance transportation agency understanding of animal life histories, their behavior and movements relative to appropriate road planning and design.

● Identify potential movement corridors (i.e., sparsely developed with at least partial forest cover, containing cliff, ledge, or talus, and minimal traffic flow) between Vermont and New York populations. Work cooperatively with New York Dept. of Environmental Conservation, TNC, other land trust organizations, the VT/NY Staying Connected "Greens to Adirondacks Linkage" program, VTrans, etc. to target and conserve these, along with other identified critical habitats, via acquisition or other means to ensure appropriate management of them.

Habitat Management

● **(Highest)** Employ existing regulatory authority via Act 250 and chip operation permits to avoid/minimize development impacts to critical habitats supporting this endangered species.

● (**Highest**) Inform, educate and encourage landowners of rattlesnake habitat to become appropriate stewards of rattlesnakes and their habitat. Management of the privately owned and municipally owned woodlands, particularly within the average dispersal range (4 km, 2.5 miles) of denning areas in the Snake Management Unit should be discussed with the landowners and/or managers. They should be encouraged to manage their lands at times and in a manner consistent with timber rattlesnake sustainability. Maintain 80% of currently forested area within 2.4 km (1.5 miles) of each known den site. This distance is based upon the average travel distance of females from the den (Brown 1993; Spear et al. 2013), increased for an extra margin of safety (NatureServe 2010). These forested areas should be contiguous with those on neighboring parcels so as to allow safe access and create continuous movement corridors.

● Within 2.5 miles of known dens employ forest management techniques designed to benefit timber rattlesnakes as follows:

-Work with foresters to properly time (during frozen ground or snow cover periods, Nov.-March) and locate logging activity to avoid the active season and minimize the chance of mortality

during logging operations. Minimize construction of new logging roads, rutting and soil disturbance and discourage unwarranted motorized, off-road use.

- Enhance the prey base by encouraging hard and soft mast species such as white/red oak/shagbark hickory/blueberries, and provide abundant coarse woody debris and structure, including entire downed tree trunks/logs and standing snags. Also encourage the creation of small openings, spatially and temporally, in the forest.

- Protect areas of rock outcroppings and talus that may be used for denning, birthing, or basking. Manage vegetation to reduce canopy cover and restore sunlight to outcrops that have been invaded by native or non-native plants that shade the area.

- Maintain naturally vegetated or undisturbed habitat adjacent to outcrops and talus areas to allow dispersal to foraging areas, excluding or removing exotic plant species.

-Appropriately buffer wetlands/riparian areas from heavy machinery/equipment use.

● Encourage the use of currently existing economic incentive programs (EQUIP) and the development of new economic incentives for private landowners to manage for timber rattlesnake and other rare species.

OUTREACH/ EDUCATION AND ENFORCEMENT

Increase Awareness and Appreciation

Ongoing public education is imperative to this species' recovery. Snakes as a group are among the most feared, misunderstood, and persecuted of species and venomous snakes are the most feared of the taxon. Lessening some of the fear and countering myths about the animal is essential in encouraging local residents and tourists to live cooperatively and safely with this species. Education of residents, landowners and land managers within the known and expected range of this species in western Rutland County should be a high priority.

Beginning in 2010, VFWD stepped up its outreach and education efforts on the rattlesnake with a significant amount of effort via a myriad of public/media outlets. Through the use of partnerships and outreach professionals, continue the education and outreach effort among targeted audiences to foster appreciation, understanding and respect for Vermont's timber rattlesnakes in order for the species to remain a part of our native fauna and wildlife heritage. Outreach should be designed to reach a wide audience using a variety of media. Targeted audiences include (but are not limited to) the following: internal publics (i.e., biologists and law enforcement) citizens of towns harboring rattlesnakes, the general public, hunters and outdoor recreationists, state parks and camping areas; landowners of critical habitat; and the news media as a means to inform the general public.

● (**Highest)** Maintain activity and availability of the "Rattlesnake Response Team" to protect animals and residents by safely moving any snakes found in close proximity to homes and workplaces. Exploit these occasions as an excellent opportunity for outreach and to appropriately inform and educate landowners about the intrinsic value and ecological benefits of rattlesnakes.

● (**Highest**) Establish communications with and provide relevant educational materials to the towns of Benson, Fair Haven, and West Haven in Vermont and Dresden, Hampton, and Whitehall in New York. Work with their select boards, planning commissions and/or conservation commissions, as well as private organizations and businesses to maintain a rural, and snake-permeable, pattern of development within the most appropriate corridor areas. Make certain they and their citizens are aware of rattlesnake removal services and important contacts.

● (**Highest**) Continue to develop and implement ongoing, local educational programs to develop and maintain public support for conservation of this unique species and other unusual reptiles that share its habitat in this region. Working to develop a local sense of pride and ownership for their unique local fauna is a useful approach.

● Develop a fact sheet/brochures to be made available to the public detailing timber rattlesnake biology, perceived and realistic risks, and conservation issues. These fact sheets should be handed out at educational events, at campgrounds, sent to schools, and posted on the web as way to quickly and efficiently communicate important biological information about these snakes. They should not be used alone but in conjunction with a list of personal contacts and other forms of information.

● Exploit the Internet as a powerful educational tool and often the first resource for those connected to it. Fact sheets should be on the web along with photographs for identification of timber rattlesnakes, eastern ratsnakes, and similar species. The website should also include basic information on rattlesnakes, related conservation efforts, how to acquire educational materials, research updates and guidelines for landowners and managers of appropriate habitat. This provides a vehicle for listing the e-mail addresses of TNC, VFWD and Vermont Reptile and Amphibian Atlas personnel who are willing to answer questions and take reports, as well as those who are willing to facilitate removal. The VFWD website has included Facebook pages/features/videos on its rattlesnake research project and generated considerable public interest/comment. Develop and foster supportive media outlets for appropriate media coverage of rattlesnake related press. Education efforts should also include school visits, educational presentations, field trips, TV, video information, and personal contact.

● Conduct reliable attitude surveys of local residents and landowners of rattlesnake habitat periodically to gauge the level of success of educational/outreach efforts to improve the public's attitudes/acceptance of rattlesnakes.

● Develop and continue to maintain a network of governmental/NGO/academic and private cooperators involved in herpetofaunal conservation to share outreach/education resources.

● **(Highest)** Deter human persecution/collection by controlling access to denning, birthing, ingress and egress areas. Posting of den sites/birthing areas, active patrols and enforcement is

essential during critical time periods of concentrated use to discourage harassment/disturbance. Employ the use of remote surveillance cameras.

● **(Highest)** Maintain communications with law enforcement, VTrans, and local officials that work in the area to set a leadership example. Annual training and updates to these personnel will help dispense some of their fears, keep them informed, increase the network of people working to preserve this species, and provide a positive conduit of information to the public. In addition, the support of these personnel will help generate reports of road-killed specimens, road crossing, and road basking areas to the Vermont Reptile and Amphibian Atlas Project or project personnel.

PARTNERSHIPS

All of the actions listed in this document involve partnerships between a variety of public and private organizations and individuals and collaborative opportunities should be pursued. Partnerships with other organizations will assist in the recovery of Vermont's timber rattlesnake populations by providing educational programs or displays, joint funding opportunities, and/or joint research opportunities. The development and maintenance of these conservation partnerships will not only help the timber rattlesnake in Vermont, but also open the door for other conservation initiatives.

Current/Potential Partners include:

The Nature Conservancy, Southern Vermont Office
The Orianne Society
United States Fish and Wildlife Service; US Department of Agriculture
VT Rattlesnake Response Team
University of Massachusetts/ University of Vermont
Wildlife Disease Health Center (USGS)
Poultney Veterinary Clinic
Vermont Herp Atlas Project
New York Department of Environmental Conservation, Division of Fish and Wildlife
New Hampshire Fish and Game
Vermont Endangered Species Committee
Vermont Department of Transportation
Vermont Forest and Parks Department
Partners in Amphibian and Reptile Conservation (PARC)
Vermont Center for Ecosystem Studies (VCE)
Audubon Vermont
Vermont Public Radio
Vermont Public Television
ECHO Lake Aquarium and Science Center
Local Volunteers
Local Conservation Commissions
Local and Regional Land Trusts
Local Schools
Local Road Commissioners

Planning Commissions (local and regional)
Select Boards

FUNDING

Adequate funding is always challenging for conservation efforts but will be necessary for successful long-term implementation and monitoring of this recovery plan (e.g., on-going support of public education, research, monitoring, and a rattlesnake removal program). Long-term funding sources and partners should be sought.

Possible funding sources include:

- VT Department of Fish and Wildlife
- US Fish and Wildlife Service (State Wildlife Grants,)
- US Department of Agriculture (NRCS-WHIP)
- Private foundations/NGO's and individuals
- Lake Champlain Basin Program

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Appendix

Table 2. Annual home range sizes for 22 telemetered timber rattlesnakes (*Crotalus horridus*) monitored with radio telemetry in 2011 and 2012 in west-central Vermont. MCP = minimum convex polygon. Prop of href = proportion of the reference bandwidth used to select the bandwidth for the hprop 95% and 50% fixed kernel utilization distributions (UD), following Berger and Gese (2007). No. of activity centers = number of distinct polygons generated with the 50% fixed kernel UD. Rattlesnakes marked with an (*) did not have a contiguous 95% href UD with no lacuna.

Year	Snake ID	Sex	MCP (ha)	Prop. of href	95% UD hprop (ha)	50% UD hprop (ha)	No. activity centers	95% UD href (ha)	50% UD href (ha)	No. activity centers
2011	CH001	Male	377.90	0.5	622.62	153.51	2	1245.58	325.77	1
2011	CH004	Male	489.36	0.7	690.42	152.28	1	973.44	213.62	1
2011	CH007	Male	123.28	0.7	688.03	155.95	2	1106.13	269.25	2
2011	CH009	Male	186.42	0.4	425.61	90.43	1	889.40	205.78	1
2011	CH023	Male	229.62	0.6	368.44	64.99	2	629.35	143.04	2
2011	CH024	Male	141.16	0.5	324.21	72.20	2	707.31	187.06	2
2012	CH028	Male	559.55	0.5	1173.21	254.67	2	2911.38	744.85	2
2012	CH080	Male	186.88	0.5	766.51	209.89	2	1794.51	486.11	2
2012	CH108*	Male	339.60	1.0	861.00	189.56	2	861.00	189.56	2
2012	CH110	Male	35.07	0.6	168.82	41.46	2	329.55	88.04	2
2012	CH111	Male	301.50	0.5	594.37	163.44	4	1356.16	381.38	1
2012	CH112	Male	160.55	0.7	392.54	107.19	3	570.86	164.87	2
2012	CH113	Male	138.21	0.8	944.17	219.88	2	1272.70	303.72	2
2012	CH117	Male	352.53	0.5	737.50	202.33	2	1559.32	399.29	1
2012	CH119	Male	234.51	0.5	582.26	137.50	3	1284.81	297.43	1
2012	CH124	Male	62.24	0.6	146.78	32.24	2	211.39	53.66	2
2012	CH202	Male	119.66	0.4	187.87	44.59	3	492.63	135.82	1
2012	CH095	Female	282.40	0.8	777.38	176.16	2	997.16	240.94	2
2012	CH116	Female	26.09	0.4	43.14	10.37	3	115.09	33.63	1
2012	CH129*	Female	14.81	1.0	32.10	6.09	1	32.10	6.09	1
2012	CH123*	Pfemale	13.22	1.0	127.29	22.13	1	127.29	22.13	1
2012	CH128	Pfemale	19.51	0.8	175.47	36.51	2	204.14	43.04	2
	Male	Mean	237.53	0.59	569.08	134.83	2.18	1070.32	269.96	1.59
		SE	35.54	0.04	69.84	16.67	0.18	156.19	40.77	0.12
	Female	Mean	107.76	0.73	284.21	64.21	2.00	381.45	93.55	1.33
		SE	87.38	0.18	246.61	55.99	0.58	308.79	74.12	0.33
	Pfemale	Mean	16.37	0.90	151.38	29.32	1.50	165.72	32.59	1.50
		SE	3.15	0.10	24.09	7.19	0.50	38.43	10.46	0.50
	Total	Mean	199.73	0.64	492.26	115.61	2.09	894.15	224.32	1.55
		SE	33.10	0.04	68.30	16.36	0.16	144.06	37.38	0.11

Table 6. Outbound migration movement statistics for 22 telemetered timber rattlesnakes (*Crotalus horridus*) monitored with radio telemetry in 2011 and 2012 in west-central Vermont. Movement statistics for other movements were calculated using all movement data excluding outbound migration movements.

Year	Snake ID	Sex	Number of outbound migration movements	Mean bearing (dg)	Length of the mean vector (r)	Mean outbound migration turn angle (dg)	Length of outbound migration (km)	Mean outbound migration rate (m/day)	Mean turn angle of other movements (dg)	Length of other movements (km)	Mean rate of other movements (m/day)
2011	CH001	Male	8	135.01	0.90	31.85	2.91	103.40	59.82	8.15	100.02
2011	CH004	Male	12	97.51	0.63	33.74	5.07	158.16	107.06	10.49	86.10
2011	CH007	Male	4	42.90	0.95	21.00	3.43	245.12	72.86	6.30	56.57
2011	CH009	Male	6	44.03	0.93	39.92	3.39	207.24	74.44	8.01	72.16
2011	CH023	Male	8	77.67	0.93	34.10	2.93	132.98	92.28	8.29	84.15
2011	CH024	Male	6	37.14	0.79	53.92	3.42	105.99	76.83	4.48	40.41
2012	CH028	Male	7	50.50	0.83	61.98	6.41	184.86	63.07	7.73	62.40
2012	CH080	Male	3	51.81	0.98	30.49	4.34	227.48	78.79	7.18	90.94
2012	CH108	Male	2	100.72	0.91	103.00	2.99	277.95	88.16	9.70	83.22
2012	CH110	Male	8	118.70	0.88	59.44	1.98	56.18	61.47	2.93	26.50
2012	CH111	Male	6	44.03	0.79	41.24	4.26	206.99	88.91	16.08	161.68
2012	CH112	Male	4	77.34	0.50	105.33	3.38	94.54	79.29	6.46	102.58
2012	CH113	Male	8	42.28	0.73	32.46	4.30	148.79	79.15	13.35	181.85
2012	CH117	Male	7	48.15	0.86	32.51	5.32	185.46	70.10	7.55	85.28
2012	CH119	Male	4	39.12	1.00	44.76	3.99	147.16	84.52	6.70	79.22
2012	CH124	Male	1	147.07	NA	136.24	0.97	46.05	99.26	6.99	99.64
2012	CH202	Male	3	88.23	0.98	52.07	3.34	179.64	80.37	6.16	96.79
2012	CH095	Female	3	80.90	0.91	85.50	3.14	93.60	62.07	5.48	57.87
2012	CH116	Female	9	162.80	0.91	52.51	1.49	33.97	86.95	1.75	48.22
2012	CH129	Female	2	186.53	0.96	72.19	0.44	73.03	61.56	1.86	59.97
	Male	Mean	5.71	73.07	0.85	53.77	3.67	159.29	79.79	8.03	88.79
		SE	0.67	8.70	0.03	7.72	0.31	15.69	3.12	0.75	9.17
	Female	Mean	4.67	143.41	0.92	70.06	1.69	66.87	70.19	3.03	55.35
		SE	2.19	32.00	0.02	9.58	0.79	17.49	8.38	1.23	3.62
	Total	Mean	5.55	83.62	0.86	56.21	3.37	145.43	78.35	7.28	83.78
		SE	0.64	10.18	0.03	6.77	0.32	15.44	2.95	0.77	8.24

Table 7. Annual movement statistics for 22 telemetered timber rattlesnakes (*Crotalus horridus*) monitored with radio telemetry in 2011 and 2012 in west-central Vermont. Pfemale refers to pregnant females. SVL refers to snout vent length. Meandering ratios were not calculated for three rattlesnakes because they were not captured near the hibernacula and are therefore not comparable to the other rattlesnakes.

Year	Snake ID	Sex	Mass (g)	SVL (cm)	No. of locations	Median location interval (days)	Total distance moved (km)	Maximum displacement (km)	Meandering ratio
2011	CH001	Male	1100	118	26	3.0	11.06	4.08	0.63
2011	CH004	Male	840	104	41	3.0	15.56	3.52	0.77
2011	CH007	Male	1150	118	33	4.0	9.78	3.40	0.65
2011	CH009	Male	1190	121	37	4.0	11.42	3.37	0.71
2011	CH023	Male	1190	121	38	3.5	11.22	2.99	0.73
2011	CH024	Male	650	93	32	4.0	7.90	3.43	0.57
2012	CH028	Male	1170	116	31	5.0	14.30	5.72	0.60
2012	CH080	Male	1260	106	26	4.0	11.77	4.59	0.61
2012	CH108	Male	1310	125	36	5.0	12.96	3.36	0.74
2012	CH110	Male	1270	116	27	5.0	4.91	2.01	0.59
2012	CH111	Male	1290	122	32	5.0	20.34	3.93	0.81
2012	CH112	Male	810	98	22	5.0	9.39	1.93	0.79
2012	CH113	Male	1205	116	28	4.0	17.65	4.27	0.76
2012	CH117	Male	1195	112	28	5.0	12.95	4.52	0.65
2012	CH119	Male	820	102	27	4.0	10.69	4.25	0.60
2012	CH124	Male	895	90	26	4.0	8.13	1.45	0.82
2012	CH202	Male	900	106	26	4.0	9.53	3.63	0.62
2012	CH095	Female	700	100	24	4.0	9.37	3.77	0.60
2012	CH116	Female	900	91	32	3.0	3.49	1.55	0.56
2012	CH129	Female	880	105	23	4.0	2.40	1.52	NA
2012	CH123	Pfemale	920	96	30	3.0	1.54	1.25	NA
2012	CH128	Pfemale	830	103	25	4.0	2.96	1.41	NA
	Male	Mean	1073	111	30	4.2	11.74	3.56	0.69
		SE	50.03	2.58	1.27	0.17	0.91	0.26	0.02
	Female	Mean	827	99	26	3.7	5.09	2.28	0.58
		SE	63.60	4.10	2.85	0.33	2.16	0.75	0.02
	Pfemale	Mean	875	100	28	3.5	2.25	1.33	NA
		SE	45.00	3.50	2.50	0.50	0.71	0.08	NA
	Total	Mean	1022	108	30	4.1	9.97	3.18	0.67
		SE	44.42	2.31	1.09	0.15	1.04	0.27	0.02