



# American Marten Reintroduction

A Feasibility Assessment  
for Pennsylvania

2022



# American Marten Reintroduction: A Feasibility Assessment for Pennsylvania

## Prepared by:

**Thomas J. Keller, Wildlife Biologist, M.Sc.**

Furbearer Program  
Game Mammals Section  
Bureau of Wildlife Management  
Pennsylvania Game Commission  
2001 Elmerton Avenue  
Harrisburg, Pennsylvania 17110

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## Introduction

The American marten (*Martes americana*, Turton and Linne 1806), also known as pine marten, was once present within the northern forest eco-community (Laurentian forests) of Pennsylvania. Due to near statewide deforestation between 1650-1920 and unregulated harvest, most martens had disappeared from the state with complete extirpation of a self-sustaining population occurring by the beginning of the 20<sup>th</sup> century (Williams et al. 1985, Powell et al. 2012).

The purpose of this assessment is to determine the feasibility of reintroducing this native species to the Commonwealth. The assessment focuses on providing important ecologic background for marten, historic population and habitat information in Pennsylvania, current habitat suitability, prey abundance, potential impacts to other species, future climate impacts, and impacts from interspecific competition. This document also focuses on biologic, social, economic, and cultural considerations for reintroduction including public opinion. Information is gathered from a combination of literature review, highlighting preceding research and reintroduction efforts, as well as expert opinion from 15 marten biologists representing 7 states. Sixty-five individuals representing 23 organizations were invited to review this document and provide comment. Over 1,100 comments were solicited, and most were addressed throughout the revision process. The assessment culminates with a recommendation and next steps for moving forward. Guidance for this assessment was provided by the **Pennsylvania American Marten Working Group**, a collaborative of federal, state, academic, and Non-Governmental Organization (NGO) partners working together for wildlife. This document satisfies goal 1.3a of the *Pennsylvania Game Commission Strategic Plan FY2020-2023* (PGC 2020).

## Historic Background of Martens in Pennsylvania

The American marten was known to exist throughout much of the northwest and northcentral regions of the state (Williams et al. 1985). Surprisingly, however, only one prehistoric record exists from a location in Bedford County, near the town of New Paris, titled the Number 4 Sinkhole (Guilday et al 1964). Skeletal remains from a single individual were found here during excavation dating to 11,300 Before Present. Williams et al. (1985) hypothesized that this may be due to the martens 'arboreal nature', or climbing ability, that would have prevented it from being trapped within similar sites. This site was studied extensively, whereas other locations within the state have not received the same attention, therefore possibly explaining the lack of other prehistoric evidence. Others postulated that native Americans may have considered the marten sacred and not utilized its pelt or meat. Although it's not clear if native tribes in Pennsylvania held the marten in a place of protection, we know other tribes from the upper mid-west and northwest coast, such as the Mi'kmaq, Ottawa, Wabanaki, Kootenai, Ojibwe, Tlingit, Menominee, Innu, and Abenaki all developed legends or stories about the marten or used the marten as a representative clan animal (NLA 2020).

Although marten range was thought to extend as far south as Tennessee and North Carolina (Krohn 2012), historical accounts in Pennsylvania documented by Rhodes (1903) and Williams et al. (1985) focus primarily within the counties of Clinton, Potter, Cameron, and McKean (Fig. 1). There are also records from Crawford, Elk, Forest, Luzerne, Tioga, Wayne, Wyoming, Pike, Monroe, Columbia, and Sullivan counties. The earliest record comes from McKean and Warren counties in 1821 and they continue throughout the marten's range within the state until the early 1900s. Although it's largely believed that extirpation occurred by the turn of the 20<sup>th</sup> century, several records have occurred in later years, 3 from the 1950s-60s in Potter and

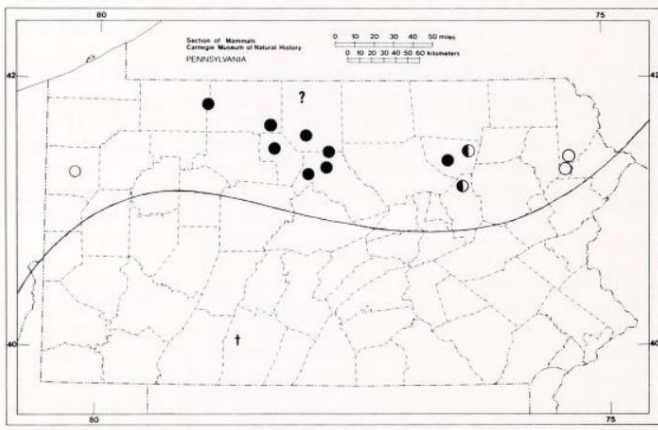


Figure 1. Estimated historic range (North of line) with historical record locations. Solid black dots represent historical records of marten captured or killed. Open dots represent museum collection specimens without associated written historical records. Half dots represent specimens with written records. The cross represents record from archaeological site, while (?) represents sight records without the animal being acquired. (Williams et al. 1985)

Wayne counties as well as a skull collected in Mercer County in 1970. More recently, some publications (Merritt 1987) list marten as having uncertain occurrence, and hinting at natural reestablishment, but no other reports have been collected since 1970.

This extirpation follows the progressive European settlement of Pennsylvania, beginning in the mid-1600s and continuing through the late 1800s (Florin 1977). This is not unlike other documented extirpation for martens within North America (Krohn 2012). By the beginning of the 20<sup>th</sup> century, very little uncut forested areas remained in the state (Rhodes 1903), and only a handful of small patches clung to the landscape in the northern tier, holding out in the steeper and more inaccessible hollows and mountain folds (Smith 1989). This same period was prior to regulated harvest within the state. Although we don't know whether unregulated take contributed to decline and eventual extirpation, it is likely, coupled with the extreme loss of habitat, to have played some part (Allen 1942), and it is clear overall harvest within the U.S. decreased dramatically coming into the early 1900s (Obbard et al. 1987). Although it is very difficult to know the exact timing of extirpation, it can be assumed that by the early 1900s most martens were absent from their historic range in Pennsylvania. The later sightings may have occurred from transient individuals dispersing from

populations in New York.

American marten is currently classified as a furbearer within the Pennsylvania Game and Wildlife Code (PGA 1986a) even though extirpated. There is no open season for martens, and they are not considered a Species of Greatest Conservation Need (SGCN; PGC-PFBC 2015), threatened or endangered (Pa. Code 58 § 133.41). Dr. Thomas Serfass completed a reintroduction feasibility assessment in 2002 that was funded by the Pennsylvania Wild Resource Conservation Fund (Serfass et al. 2002). This document determined there was justification for a reintroduction, providing specific locations for release and citing likely habitat suitability but cautioned against expecting results like those experienced with fisher and otter reintroductions. At the time (2003), Pennsylvania Game Commission staff did not feel that this assessment addressed habitat suitability within the state adequately, and thus chose not to move forward with reintroduction efforts until further habitat evaluations occurred.

## Ecology

**Taxonomy** - American marten is known by many names including the American pine marten, American sable, and Apistanewj by the Mi'kmaq tribe. Often considered intermediate in size between the American mink (*Neovison vison*) and the fisher (*Pekania pennanti*). Martens are derived from the Order Carnivora, Family Mustelidae, and genus *Martes*. Of the 8 'true' marten species, not including fisher, wolverine (*Gulo gulo*), and tayra (*Eira barbara*), *Martes americana* falls within a sub-group called the 'boreal forest martens,' which are found across the circumboreal zone (Buskirk and Ruggiero 1994; Buskirk 1992) and largely do not overlap amongst species east to west. Fourteen subspecies were at one time recognized throughout the old and new worlds (Hall and Kelson 1959) but more recently only 8 have been widely accepted (Clark et al. 1987), and of those 8, only 5 are considered 'true' boreal forest martens, to include the American marten.

**General Characteristics** - American martens measure between 500 and 680 mm (19.7 – 26.8 in.) from nose to tip of tail with adults weighing between 500 g and 1400 g (1.1 – 3.1 lb.; Buskirk and Ruggiero 1994). Sexual dimorphism within this species is evident with males being up to 65% heavier and 15% longer than females (Clark et al. 1987) in size. The coat is made up of dense fur with long soft guard hair and coloration varies among individuals. Light brown to black hair covers the top of the head, running down the back, continuing onto the tail and stretching down each leg. In winter, a pale, whitish gray color stretches from the ears down under the chin whereas in summer this area is chocolate brown. A yellowish orange bib covers the throat and can stretch down to the chest. Like most furbearing animals, the coat thins substantially throughout spring and summer (Clark et al. 1987; Soutiere and Steventon 1981).

Having digitigrade, 5 toed feet with semi-retractable claws, these animals can move vertically through the canopy as quickly as horizontally on the ground surface. Their thickly furred, large feet allow for efficient weight disbursement on snow (Krohn et al. 2005, Jensen and Humphries 2019). Martens have a typical weasel body shape, which is long and thin with relatively short legs. These attributes allow them to use burrows and subnivean spaces efficiently. Combined with other attributes including a pointy snout with long whiskers for optimal hunting in tight, narrow locations such as tree cavities, dense understory, or within subnivean (under snow) abscesses.

**Distribution** – Current range (Fig. 2) of the American marten extends from the far northeast of North America in Newfoundland, across the northern forest boundary in Canada, stretching up into Alaska. The western edge of the range encompasses British Columbia down through parts of the Pacific northwest and into northern California following the Cascades and the Sierra Nevada ranges. It should be noted that these western martens are often considered Pacific marten (*Martes caurina*), although there's

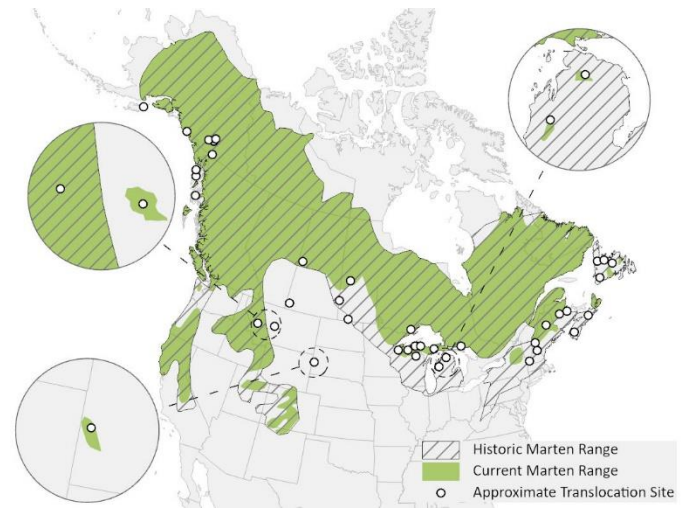


Figure 2. Historic and current distribution of American and Pacific martens in North America with historic translocations shown. E. Kerstetter, 2022 (Data from Williams et al. 2007, Powell et al. 2012 and Pauli et al. 2022)

still question as to where the transition zone is between Pacific and American marten. Populations stretch down through the Rocky Mountains as far south as New Mexico. Following the forested landscape, the range retreats up into mid-Alberta, Saskatchewan, and Manitoba before again coming south into Minnesota and the upper peninsula of Michigan. Within New England, some populations exist as far south as the Adirondacks of New York and further north into Vermont (Moruzzi et al. 2003), Maine and then back into Canada as far northeast as Prince Edward Island (Clark et al. 1987; Hall 1981; Buskirk and Ruggiero 1994).

Historic southern range within the mid-West and East would have encompassed northeastern North Dakota, down through the entirety of Wisconsin, Michigan, continuing as far south as southeastern Ohio, northern West Virginia, and the northern two thirds of Pennsylvania, finally running north through all New England. Fossil records to the east indicate *Martes americana* as far south as Tennessee as well as in Virginia, West Virginia, and Pennsylvania. To the west, fossils have been found in sites in the Yukon Territory, Idaho, Wyoming, and Colorado (Clark et al. 1987).

Multiple reintroduction projects have been conducted throughout the current and historic range (Fig 2) to include Maine, Vermont (Moruzzi et al.,

2003), Wisconsin (Williams et al., 2007), the upper and lower peninsulas of Michigan (Hiller et al. 2011; Williams et al. 2007), South Dakota (Buskirk and Ruggiero 1994), Montana (MFWP 2020), Idaho, New Hampshire, Wyoming, several Alaskan islands, and throughout Canada (Burriss and McKnight, 1973). Further details on previous reintroductions are provided in *Marten Reintroduction Efforts* section under *Translocation and Reintroduction*.

**Reproduction** – Both male and female martens are polygamous (Proulx and Aubry 2017). Breeding season averages 35 days and generally occurs within the months of July and August but can begin as early as late June in Alaska and end as late as early September in more southern locales (Clark et al. 1987; Buskirk and Ruggiero 1994). Following fertilization, delayed implantation of the blastocysts occurs for anywhere between 190-250 days (Clark et al. 1987; Hamilton 1943). After implantation, gestation lasts 27 days prior to birth. Between 1-5 kits (avg. 2.85; Strickland and Douglas 1987) are born altricial between March through May weighing an average of 28 g (Strickland et al. 1982, Buskirk and Ruggiero 1994). Young are weaned by day 42 (Mead 1994, Buskirk and Ruggiero 1994) and are actively moving out of the maternal den by day 46 (Clark et al. 1987). At 15 months, marten reach sexual maturity, with some females producing first time litters at 24 months (Strickland et al. 1982, Buskirk and Zielinski 1997). Fecundity and recruitment can vary widely (Clark et al. 1987) and is thought to potentially be driven by food availability or environmental stress (Thompson and Colgan 1987, Buskirk and Zielinski 1997).

**Dispersal, Home Range and Minimum Population Viability** – After accompanying the adult female outside of the den during late spring through summer, young marten disperse from late-summer through early winter (Buskirk and Zielinski 1997, Buskirk and Ruggiero 1994, Clark et al. 1987). Dispersal distances vary between location and are likely a result of habitat quality and pre-existing territories. The average dispersal distance reported included 33.3 km in Oregon (Bull and Heater 2001)

and 5.13 km in Ontario (Broquet et al. 2006) while unpublished data from Minnesota (M. J. Joyce, University of Minnesota, unpublished data) was 4.3 km for males and 6.4 km for females. Pauli et al. (2012) found a range of 15-40 km from research that looked at both American and Pacific marten in southeastern Alaska and northern British Columbia. Although not typical, martens can disperse long distances and have been reported traveling over 200 km in several instances (Johnson et al. 2009, Moruzzi et al. 2003).

Martens, like most mustelids, exhibit what is called intrasexual territories where territories are closely defended within the same sex, but where overlap occurs between sexes (Powell 1979, Buskirk and Ruggiero 1994). Home range size for males is larger than for females in most cases, although some research has shown comparable sized ranges between sexes (Smith and Schaefer 2002). This study compiled historical data and showed the wide variation between 15 study sites with female marten home ranges from 2-27.6 km<sup>2</sup> and males from 2.6-45 km<sup>2</sup>. Dumyahn et al. (2007), in northern Wisconsin, found an average winter home range size of 3.29 km<sup>2</sup> (males=4.25 km<sup>2</sup>, females=2.32 km<sup>2</sup>). Another Wisconsin project, centered on translocation of martens from Minnesota (Woodford et al. 2013), compared not only sex but age, with adult males=16.19 km<sup>2</sup>, adult females=4.81 km<sup>2</sup>, juvenile males=11.57 km<sup>2</sup> and juvenile females=10.27 km<sup>2</sup>. This research showed martens traveling an average of 4.6 km over an 18-day period before establishing territory as these were translocated individuals. Kujawa (2018), when researching home range of martens in a reintroduced population in the northern Lower Peninsula of Michigan, found a mean of 12.4 km<sup>2</sup>. Home range variability seems to be driven by a variety of factors, to include habitat quality, typing, connectivity, and availability as well as prey abundance (Buskirk and Ruggiero 1994, Thompson and Colgan 1987, Soutiere 1979). Variability amongst documented home ranges can also depend on monitoring and relocation methodology. It must be understood that making comparisons between reported results that may be measuring home range

during differing seasons or using a variety of methods can be difficult.

Minimum Viable Population (MVP) can be an important aspect of a species long-term survival and management. Genetics become a critical part of this estimation, particularly within populations that are isolated or experience little to no gene flow. Slough (1994) recommended that MVP for American marten is 50 breeding individuals for short-term genetic success, while long-term goals may reach upwards of 500. At 50, however, genetic fitness can be maintained. He recommended, based on research from Strickland et al. (1982), a stable population of 50 individuals would require an area ranging from 42-125 km<sup>2</sup> of connected habitat. Population viability modeling work on populations in Michigan found that when habitat carrying capacity of marten exceeded 100 individuals, loss of marten genetic heterozygosity was minimal over a 100-year period, whereas below that threshold, it decreased substantially (Hillman 2014, Hillman et al. 2017). Research within Wisconsin (Grauer et al. 2019) explored two separate reintroduced populations and how immigration proved critical to preventing extinction over time. This research demonstrated the critical importance of maintaining genetic diversity in an isolated, reintroduced population.

**Diet** – Martens are considered a facultative generalist, feeding on a large variety of available food types by season (Zhou et al. 2011). Martens are both active predators as well as opportunistic scavengers. Martens have been documented to feed on mammals both larger than and smaller than themselves, including small mammals, reptiles and amphibians, birds and bird eggs, insects, both hard and soft mast, earthworms, and carrion (Clark et al. 1987, Buskirk and Ruggiero 1994). As is seen in other mustelids such as fisher (McNeil et al. 2017), martens also exhibit intraspecific consumption (Thompson and Colgan 1990, Carlson et al. 2014, Zielinski et al. 1983). Marten have even been observed feeding at sap wells of maple trees (*Acer spp.*) created by yellow-bellied sapsuckers

(*Sphyrapicus varius*) as reported by Kitching and Tozer (2010).

Prior diet study comparisons (Buskirk and Ruggiero 1994) as well as a comparison of 13 historic diet studies (Appendix 1) compiled in this assessment, paints a very clear picture of not only the diversity of food items but also preference. Small mammals (voles, mice, and shrews) make up the bulk of the marten diet (>68% frequency of occurrence [FO]). Within this group, and as most literature states, the red-backed vole (*Myodes gapperi*) is the most common prey item (26.1% FO) throughout the marten range (Martin 1994, Clark et al. 1987, Bull 2000, Thompson and Colgan 1987 and 1990, Cumberland et al. 2001, Hales et al. 2008). The *Microtus* genus makes up another large portion (24.2% FO) followed by the *Peromyscus* genus (13.5% FO), *Blarina* genus (11.9% FO), and *Sorex* genus (10.7% FO).

The percent frequency equals the number of occurrences of a prey item divided by total number of stomachs, intestines, and/or fecal samples multiplied by 100. Note that percent frequency of occurrence is the most common measurement of diet composition and sums to more than 100% in most cases

Plant materials make up the next largest FO at 21.7%, with a major percentage coming from soft mast (e.g., berries) and the rest from a variety of grasses, leaves, lichen, etc. The bird class has a FO of 12.3%, with ruffed grouse (*Bonasa umbellus*) at 4.6% FO and 'Other Birds' at 7.4% FO. The *Sciurids* (squirrel grouping) have a FO of 11.5% with members ranging from 1.5% (*Glaucomys spp.*) to 6.7% (*Tamiasciurus hudsonicus*). *Lagomorphs* (rabbits and hares) follow with a FO of 9.3%, the majority reflected solely by snowshoe hare (*Lepus americanus*). The *Mustelid* grouping had a FO of 2.7%, with American martens comprising 1.62%. Within the 'Other' category (23.3% FO), insects led with 17.8% followed by cervid carrion at 6.9% FO. This category also included fish, amphibians, reptiles, and a western woodrat species (*Neotoma*



*cinerea*).

Diet can be dictated by seasonality, prey abundance, or prey access (Zielinski et al. 1983, Weckwerth and Hawley 1962, Buskirk and Ruggiero 1994). Use of items such as soft mast or insects peak in late summer through early fall while winter sees marten diet heavily skewed towards mammals (Thompson and Colgan 1990, Buskirk and Ruggiero 1994, Raine 1981). Thompson and Colgan (1990) found that marten in Ontario expanded their diet niche during years when common prey species were less abundant. With the effect of mast production on prey abundance, several researchers have found important ties to marten harvest in relation to mast availability (Jensen et al. 2012, Jakubas et al. 2004). Martens have also been considered an important species for seed dispersal given their penchant for a large variety of fruits and their home range size or dispersal distances (Willson 1993). It should be noted that although most diet research is reported as percentage frequency of occurrence, Cumberland et al. (2001) suggested that assessment of prey availability should rather focus on the importance of those species (i.e., hare, grouse, and squirrel) with the highest caloric value, measured instead in overall biomass. This doesn't negate the fact that small mammals still make up most of the marten's diet or that martens can't persist on small mammals, only that in some areas of their range, larger prey makes up a larger portion of their caloric intake depending on time of year.

**Mortality** – Sources of mortality for martens varies between natural predation, human caused (harvest or roadkill), as well as disease and parasites. As with other species, exposure (Bull and Heater 2001) and starvation (Hearn 2007) occur within marten populations and has been documented as causes of mortality for this species. Toxoplasmosis, Aleutian disease, and plague (western populations) have all been detected in marten at various rates, although were not found to have population-level impacts (Strickland et al. 1982, Zielinski 1984, Buskirk and Ruggiero 1994). Fredrickson (1990) found that canine distemper can cause high mortality as it

spreads throughout an area. Martens host a large variety of ectoparasites and several endoparasites (Clark et al. 1987, Strickland and Douglas 1987); however, none have been shown to cause negative impacts on populations. A detailed study on serosurvey, hematology and causes of mortality relating to a reintroduced population of marten in Michigan (Spriggs et al. 2018) found that although martens contained antibodies for several viruses and even a high percentage with verminous or granulomatous pneumonia, the primary natural cause of mortality was predation followed closely by trapping, where legal.

Reported mammalian species preying on marten include bobcat (*Lynx rufus*; Bull and Heater 2001), fisher (Payer and Harrison 1999, McCann et al. 2010), coyote (*Canis latrans*; Woodford et al. 2013), red fox (*Vulpes vulpes*; Buskirk and Ruggiero 1994, Hearn 2007), and other martens (Bull and Heater 2001, Thompson 1986, Thompson and Colgan 1990, Carlson et al. 2014, Zielinski et al. 1983). The most common raptor species to take martens are the great-horned owl (*Bubo virginianus*; Baker 1992, Buskirk and Ruggiero 1994), eagles (*Accipitridae spp.*) and the northern goshawk (*Accipiter gentilis*; Bull and Heater 2001, Squires 2000). Clark et al. (1987) reported that none of these species poses a significant threat to marten populations. More recent research (Jensen et al. 2019, Pauli et al. 2022) points to the increased potential of predation from larger mammalian predators in the absence of suitable habitat and abiotic conditions. Most mammalian predation occurred during winter, while raptors, although infrequent, took marten during the summer kit-rearing period (McCann et al. 2010, Woodford et al. 2013)

**Survival** - In captivity, martens can live 15 years and even some wild-caught martens were aged to 14.5 years (Strickland and Douglas 1987, Buskirk and Zielinski 1997), however, average age is likely much less, although there is surprisingly little information available. Harvest records from research within the Upper Peninsula of Michigan found that within a

trapped population, the majority of the harvest was yearlings while 1.5-year-olds followed closely behind, and very few individuals lived past 5.5 years (Skalski et al. 2011). Woodford et al. (2013) compared survival of two release methods for translocation in northern Wisconsin: quick release after transport (Survival = 0.80) and a 14-day conditioning period slow-release (Survival = 0.67). This study also estimated survival after the slow-release reintroduction with variation among sex (F=0.71, M=0.79) and age (J=0.66, A=0.84). Another northern Wisconsin project (McCann et al. 2010) found overall adult annual survival to be 0.81 with adult females at 0.77 and adult males at 0.85. There was no estimate of juvenile survival. Hodgman et al.'s (1994) survival results from northcentral Maine show a wide gap between sexes regardless of age with males (JM=0.64, AM=0.56) significantly less than females (JF=0.73, AF=0.76), likely a result of a larger home range and increased opportunity to encounter a trap set. Bull and Heater (2001) conducting research in northeast Oregon found a relatively low annual survival of 0.63, while Slough (1989) found some of the highest recorded, within the Yukon Territory, at 0.88 and 0.91 for females and males, respectively.

Martens are susceptible to human caused mortality (i.e., harvest or roadkill), which can reduce overall density, skew sex ratio towards females, and change age structure (Buskirk and Ruggiero 1994, Powell 1994, Strickland and Douglas 1987, Hodgman et al. 1994). Payer and Harrison (1999) found in Maine comparing adult marten survival within an un-trapped forest reserve (F=0.62, M=0.95), a trapped industrial forest (F=0.66, M=0.59), and an un-trapped industrial forest (F=0.82, M=0.84). It should be noted, however that density and age structure can fluctuate dramatically within unharvested populations (Thompson and Colgan 1987, Wekwerth and Hawley 1962, Buskirk and Ruggiero 1994). and regulated harvest provides a tool to decrease these swings in density helping to stabilize populations for ease of management (Powell 1994).

**Habitat** – The subject of marten habitat has been researched extensively throughout their range and there is a wide variety of literature available. What is generally agreed upon is that martens are a species of mature forest, with strong ties to conifers, favoring a diverse and complex structure from forest floor to canopy crown (Strickland and Douglas 1987, Clark et al. 1987, Buskirk and Ruggiero 1994, Buskirk and Powell 1994, Buskirk and Zielinski 1997, Gilbert et al. 2017). Originally thought of as a species specifically inhabiting ‘old-growth’ coniferous forests, much research has shown that the marten can inhabit a large variety of forested habitat types if abundant prey and cover are available.

Historical records describing habitat within Pennsylvania (Rhodes 1903) reflect a difference in habitat preference from northern populations. Rhodes says, “My correspondents agree in saying that deciduous, hardwood timber is preferred by this species in Pa. This seems at variance with its preferred resorts in Canada.” Martens prefer mesic over xeric forests as is reported by Buskirk and Powell (1994). Several habitat-based models have been developed (Bowman and Robitaille 2005) but none are referenced more than the model Arthur Allen developed in 1984 (Allen 1984). Allen described the two most limiting factors for suitability of winter habitat were percent tree canopy closure (>30%) and stand successional stage (pole size or larger). The two additional factors that Allen (1984) stressed were having conifers, primarily fir or spruce, as a portion of overstory (>25%) as well as the importance of downed woody debris and stumps covering the forest floor. This complex structure at ground level provides important prey habitat and access to the subnivean spaces for both hunting and thermal regulation as well as protection from predators (Buskirk and Powell 1994, Buskirk and Ruggiero 1994, Corn and Raphael 1992). Basal area of partially cut stands also plays an important role in use and Fuller and Harrison (2005) recommend retention of >18m<sup>2</sup>/ha which provides for both cover and food abundance needs.

It is well documented that martens avoid

large open areas such as new clear cuts, burns or fields that lack canopy cover (Hawley and Newby 1957, Koehler and Hornocker 1977, Soutiere 1979, Allen 1984, Buskirk and Powell 1994); however, if alternate suitable cover is available (e.g., thick early successional growth, rock or talus fields, heavy slash, or an open subnivean environment) martens have been shown to utilize non-high canopied areas (Streeter and Braun 1968, Soutiere 1979, Allen 1984, Buskirk and Powell 1994). Seasonal differences in relation to young forest openings are evident, where martens avoid openings during the winter, purportedly due to predator avoidance, while their use of these areas may expand during the summertime if early succession provides a low, dense canopy (Koehler and Hornocker 1977, Soutiere 1979, Buskirk and Powell 1994). These authors also point out that research results vary on marten use of edges, although it appears that the edge composition itself dictates use.

Of all aspects of habitat, structural complexity is likely the most important for the American marten, according to the literature review. Denning and resting sites are an important part of this complexity and having a mixture of tree cavities, exposed branches, ground based sites such as holes, dens, rock outcrops, downed woody debris, and of course access to all of these during periods of prolonged snow is critical (Buskirk and Powell 1994, Joyce et al. 2017, Sanders and Cornman 2017). The overall volume and percent cover of coarse woody debris provides greater access to subnivean spaces during winter (Corn and Raphael 1992) and speaks to the importance of this complex horizontal structure. Joyce et al. (2017) found several key observations when conducting a literature review focusing on resting microsite use. Their findings showed that a.) during winter, martens utilized sites within the subnivean layer more often than outside of it, b.) severe winter climates saw an increase in ground microsite use by martens and c.) martens used ground microsites more often than fishers. Sanders and Cornman's (2017) research, within the Lower Peninsula of Michigan, found different results with most winter (97.4%) resting sites within larger

diameter at breast height (DBH), elevated cavities (64.9%), branches (12.9%), or nests (19.6%), while summer sites (97%) focused on these same three characteristics (39.3%, 41.8%, 15.9%, respectively), with oak being the predominant tree species selected. This likely falls in line with Joyce et al.'s (2017) conclusion that within areas experiencing mild winters, marten may not require subnivean rest sites as frequently. Current research in Michigan is showing that martens using cavities within these areas are not showing a significantly higher energetic cost (M. J. Joyce, University of Minnesota, unpublished data). Denning sites from research in Michigan were found most often in live trees with large basal area (Nichols 2016).

The study of habitat fragmentation and its effects on marten populations, especially relating to connectivity between populations is evolving. When considering landscape connectivity, D'Eon et al. (2002) found martens to have moderate vagility in comparison to fellow old-growth associates with both high (northern goshawk) and low (northern flying squirrel) vagility. At the local (or home range) scale, Potvin et al. (2000) recommended keeping fragmentation below 30% over a 30-year period. Research in northeastern Utah developed recommendations that timber harvests (new harvest in combination with natural openings) remain less than 25% of landscapes  $\geq 9$  km<sup>2</sup>, and if possible cutting outwards from a single patch vs. the same area, but in well distributed smaller patches, in order to maximize contiguous mature forest (Hargis et al. 1999). Payer and Harrison (1999) recommended timber harvests less than 20% of landscapes from research conducted in Maine. Proulx (2001) conducted research on the use of connectivity corridors in British Columbia, within a highly fragmented landscape, finding that it appears martens can persist, but population viability is uncertain pending further study. Research points towards a variety of factors, including forest cover, slope, elevation, and land development that affect regional gene flow (Aylward et al. 2020), an important consideration for future persistence of a population.

## Prey Abundance in Pennsylvania

Assessing prey abundance for martens often entails extensive, multi-year small mammal trapping efforts (Haskins et al. 2020, Thompson and Colgan 1990). Very little published research focusing on Pennsylvania is available for species that make up the majority of the marten's diet (i.e., small mammals). The literature that is available generally focuses on specific locations within the state (Merritt et al. 2001) or is associated with habitat management practices (Goguen et al. 2015, Yahner and Smith 1991, Kirkland Jr. 1978). With little time to conduct prey abundance surveys in relation to this assessment, and especially over such a large area of potential habitat, Western Pennsylvania Conservancy was contracted to examine historic terrestrial small mammal data collected within this target area. The goal of this review was to determine relative abundance and species richness at the watershed level (scale of Hydrologic Unit Code 10 or HUC10). Data ranged from 1984 through 2018, and included 387 surveys during this time, with 8,368 individual captures representing 20 species.

Results of the analysis (Fig. 3; WPC 2022) identified *Peromyscus* species comprised 41% FO of captures followed by red-backed voles (19% FO), northern short-tailed shrews (*Blarina brevicauda*; 13% FO), woodland jumping mice (*Napaeozapus insignis*; 11% FO), and other shrew species (10% FO). Other small mammals (5% FO) and squirrels (1% FO) made up the remainder of guilds represented in the WPC sample.

Due to limited survey effort within the state, analyses at the HUC10 scale was challenging, with no clear patterns in species richness or relative abundance of most species guilds among HUCs. Some HUC's falling within the area of suitable habitat had little to no survey data. It should also be noted that there is inherent bias with these surveys specifically with targeting micro habitats as well as methods that often exclude larger mammals such as hares, rabbits, and squirrels which may be important for martens.

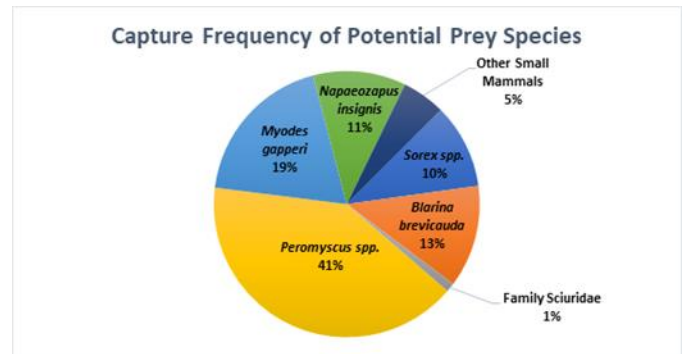


Figure 3. Percent frequency of occurrence of terrestrial small mammal guilds from 387 surveys conducted in Pennsylvania between 1984-2018 within the study area. (WPC 2022)

Despite the recognized limitation and bias within this analysis, the researchers “feel confident stating that a healthy terrestrial small mammal prey base is present...” and that “...the terrestrial small mammal prey base would not be a limiting factor for MAAM (marten)...” (WPC 2022; Appendix 2).

Concerning other mammalian prey such as rabbits and squirrels, little data exist on overall abundance within the study area, particularly with Appalachian cottontail, an SGCN species. Looking at long-term harvest reports, specifically harvest per unit effort (Johnson 2021), metrics for cottontails (2 species) and squirrels (3 species), popular small game species, have changed little and they continue to provide ample opportunity within Pennsylvania. It could be assumed that this points to stable statewide populations, although most certainly this varies by location. Focused monitoring or estimates of abundance concerning these species may be warranted both pre- and post-release of marten. If reintroduction would occur, research should in part focus on predator-prey dynamics of marten within Pennsylvania and in comparison, to past efforts throughout their range. An additional note that populations of mammalian prey can be cyclical in Pennsylvania depending on mast crop.

## Interspecific Competition and Coexistence

Understanding the relationship between marten and other meso-predators within Pennsylvania,

specifically the fisher, bobcat, and coyote, is critical to addressing whether this may be a limiting factor in the success of a marten reintroduction. When considering the fisher specifically (intraguild) having close phylogenetic relations and morphology (Jensen and Humphries 2019), North American marten distribution is much larger and at higher latitude (Douglas and Strickland 1987) and elevation (P. Jensen, NY DEC, pers. comm.); however, both species overlap significantly over large portions of their ranges exhibiting strong sympatry (Zielinski et al. 2017, Hagmeier 1956). Rosenzweig (1966) and Raine (1981) suggested that this sympatry occurred through niche partitioning, specifically with differing food sizes and martens' ability to hunt within the subnivean space. Krohn et al. (1995, 1997) postulated that frequent "deep, soft snow" events limited fisher use of habitat, thus reducing competition with marten. Zielinski et al. (2017) found that snowpack condition, minimum temperature, elevation, and precipitation amount appeared to drive niche differentiation, although they discovered there was some overlap within a sympatric zone.

Research from the Rocky Mountains of Alberta has shown the importance of spatial heterogeneity with fisher and marten coexistence at the landscape scale while exhibiting spatial segregation at the local or regional level due to differences in habitat selection (Fisher et al. 2013). Building on this idea of heterogeneity on the landscape scale, Manlick et al. (2020) compared the difference between a natural system (Voyageurs National Park [VNP], MN) and a human dominated landscape (Chequamegon National Forest [CNF], WI). They found that even though change in forest composition is similar within the two, the combination of reduced structural and taxonomic diversity within the forest at CNF as well as increased human-based development and fragmentation led to high niche overlap, while conversely, the more contiguous, diverse, less human altered forests of VNP showed competitor coexistence. When reviewing the marten reintroduction efforts within Wisconsin, Manlick et

al. (2017) found similar results, including that "deep, uncompressed snow" restricted fisher activity. This research also identified strong dietary and habitat selection overlap with fisher contributing to niche compression and increased competition. The primary driver identified in Wisconsin was a homogenized landscape following Euro-American settlement land clearing and forestry practices, which promoted fragmented, young, even aged forests (Schulte et al. 2007, Manlick et al. 2017). Within the central Adirondacks of New York, Jensen and Humphries (2019) built on this idea of abiotic (or climatic) conditions (snow depth, density and persistence, temperature, etc.) working in tandem with biotic conditions (productivity, competitor abundance, etc.). Their research found that factors such as snow depth may not be as critical as is productivity, temperature, forest maturity and elevation. They also found that martens were competitively excluded by fisher and coyotes when overall productivity (high biomass) and temperatures increased, whereas marten were able to co-exist when these conditions were reversed.

One of the best and most recent papers that synthesizes research conducted on competition between marten and fisher is Pauli et al. (2022). Their review and summary of previous research has led to several conclusions focusing on what they consider the 'three critical niche axes', those being diet, space, and time, all important to the idea of ecological niches, niche differentiations, and coexistence amongst similar species. The generalist nature of diet for both species would point to competitive overlap, however the authors note the potential for divergence if there is a diversity of prey. Fisher and marten select for similar habitat, that being forest structural complexity. Pauli et al. (2022) also stress the importance of habitat partitioning through habitat and spatial heterogeneity, which occur through a diverse forest composition, age class, and structure as well as climate, elevation, and topography. They also note the importance of temporal partitioning, when the subordinate species (marten) would avoid interaction with the dominant species (fisher) through changes in where and when

habitat would be used, whether that be a daily decision or seasonal shifts. There are examples within the literature where this is and is not (Croose et al. 2019) occurring between these two species. The authors point out the potential impact of competitive interactions with other species (bobcat, coyote, etc.) and the need for additional research within this field.

## Snowfall, Forest Composition, and the Future of both in Pennsylvania

**Importance of Snow to Martens** - As noted previously within the habitat needs of American marten, snow cover during winter can act as an important aspect in providing thermal protection and offer a competitive edge to marten over other meso-carnivores (Raine 1981, Krohn et al. 2005) such as fisher, bobcat, and coyotes, by giving them access to winter food resources within the subnivean space (Buskirk and Powell 1994). The reported minimum snow depth for subnivean establishment varies from 10 cm (Thompson et al. 2018) to 20 cm (Pruitt 2005) and will provide suitable stabilized temperatures. Snow depth can vary based on forest structure, particularly canopy cover (Varhola et al. 2010) as well as a variety of landscape characteristics such as latitude and topography (Thompson et al. 2018). Much subnivean research has also focused on the importance of additional abiotic conditions such as snowpack, which constitutes density, persistence, surface hardness, compaction (Pauli et al. 2022, Berteaux et al. 2017), elevation and temperature (Jensen and Humphries 2019). This combination of factors determines a marten's ability to access the subnivean, the length of time it is available, and the fisher's ability to compete over the winter season (see *Interspecific Competition and Coexistence* section).

**Snowfall in Pennsylvania** - Average annual snowfall in Pennsylvania varies widely throughout the state ranging from below 50.8 cm in the southeast to over 264 cm in the northwest (Fig. 4; NOAA 2022). Snowfall in the state is largely dependent on latitude, elevation, and lake effect snow from Lake

Erie. Latitudinally, the Commonwealth sits between 42.269°N at its northernmost point (Erie County) and 39.721°N at its most southern (Greene County). Elevations within the state range from a low at sea level within the Delaware River in the southeast to a high of 979.3 MSL at Mt. Davis, in Somerset County in the southwest. Within much of the large, contiguous forested areas of the state found in the northern tier, elevation ranges from 426 MSL to over 670 MSL. Much of the potential habitat for marten in the state lies within several different physiographic provinces, including the High Plateau, Deep Valleys, Pittsburgh Low Plateau, and Glaciated High Plateau sections (DCNR 2018). Average annual snowfall across these sections varies from 91 cm to over 243 cm (NOAA 2022). Variables that account for snowpack within the state are challenging to determine and national research conducted on this metric has a large resolution in comparison to the scale of the Pennsylvania specific habitat model.

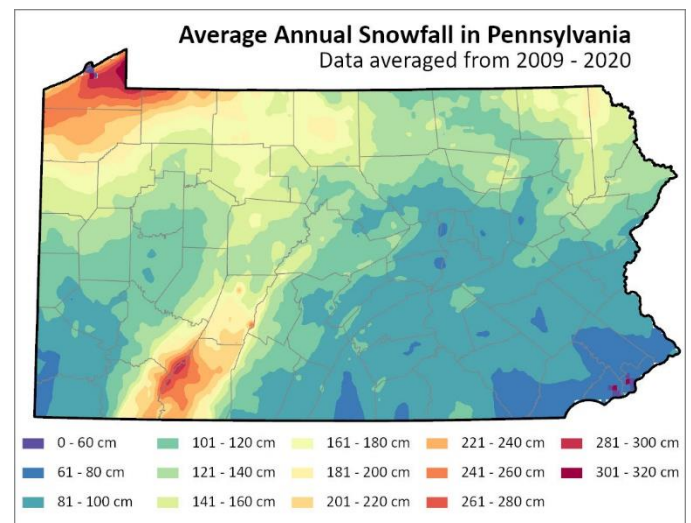


Figure 4. Average annual snowfall in Pennsylvania. E. Kerstetter 2022.

**Historic Forest Composition** - The pre-European settlement northern forests of Pennsylvania consisted of large diameter, old growth conifers, primarily white pine (*Pinus strobus*) and eastern hemlock (*Tsuga canadensis*), as well as a mix of hardwoods such as black cherry (*Prunus serotina*), various oaks (*Quercus spp.*), hickories (*Carya spp.*), white ash (*Fraxinus americana*), American beech (*Fagus*

*grandifolia*) and American chestnut (*Castanea dentata*) (Hough and Forbes 1943, Nowacki and Abrams 1994). Disturbance at this time occurred from a variety of natural sources including windfall, insect outbreaks, ice glazing, as well as both natural and anthropogenic fire (Black and Abrams 2005). It's estimated that prior to settlement, forest land in Pennsylvania equaled 28.6 million acres (Albright et al. 2017). Following the intense logging of the 19<sup>th</sup> century, forest composition changed throughout the state. By the turn of the 20<sup>th</sup> century, it was estimated that just over 9 million acres (32%) remained (Rothrock 1895). This change was dictated through the species value at the time of cutting, seed tree removal, intensive fires within standing slash, and increased herbivory of new growth from species lacking natural predators such as white-tailed deer (*Odocoileus virginianus*) (Tilghman 1989) and porcupine (*Erethizon dorsatum*) (Hough and Forbes 1943). Previous white pine dominated stands saw an increase in white oak, red maple (*Acer rubrum*) and chestnut during second and third growth. Hardwood-hemlock stands saw an increase in beech, maple (*Acer spp.*) and birch (*Betula spp.*) species (Hough and Forbes 1943) during their second and third growth. Since that time, species such as beech, ash, and hemlock continue to face threats from Beech Bark Disease (*Neonectria spp.*; Held and Jones-Held 2014), Beech Leaf Disease (*Litylenchus crenatae mccannii*), Emerald Ash Borer (*Agrilus planipennis*), and Hemlock Woolly Adelgid (*Adelges tsugae*; Cessna and Nielsen 2012) respectively. Other forest pests have wrought havoc on the forest in past years including the spongy moth (*Lymantria dispar*), where during the years 2006-2008, over 2 million acres of forest land were defoliated from infestation (Albright et al. 2017).

**Current Forest Composition** - Pennsylvania currently contains approximately 16.7 million acres of forested land (USDA 2019), which makes up approximately 58% of the total land area. Development and agriculture continue to be the two primary reasons for loss of forested area, although more forest was gained than lost between 2009 and 2014 (Albright et al. 2017). Albright et al. (2017)

also reported that currently 56% of forest land is considered 'core' forest (minimum patch size of 1,544 ac.) while 24% has 'high integrity' when it comes to determining fragmentation (Fig. 5). Public (30%) vs. private (70%) ownership (Fig. 6) is important to consider for the state's forest lands and how they are managed. Of that 30% of publicly owned forest land, 27% is owned by state and local governments (USDA 2019).

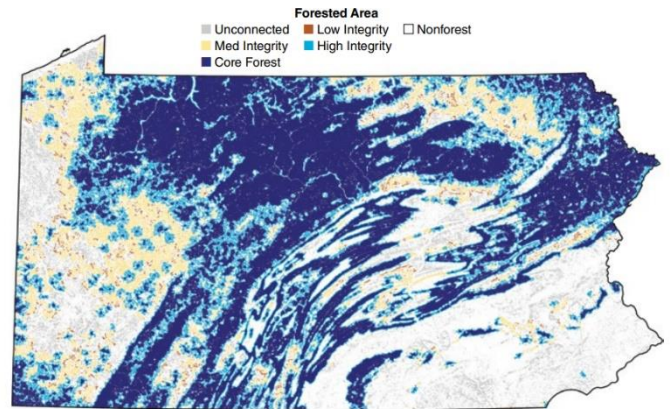


Figure 5. Core forest area within Pennsylvania. Albright et al. 2017.

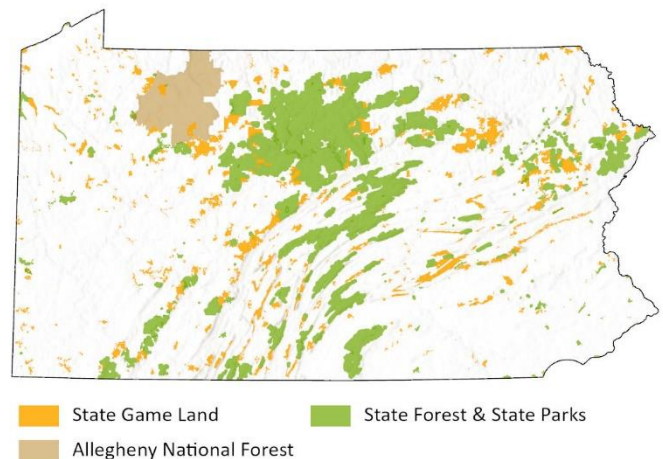


Figure 6. Public land ownership within Pennsylvania. E. Kerstetter 2022.

The most recent Forest Inventory Assessment (FIA) data showed Pennsylvania as having a very diverse forest, with 101 tree species and 16 forest-type groups. The most common FIA 'groups' across the northern tier regions were oak/hickory, maple/beech/birch, followed by white pine/red pine/hemlock. Large diameter classes are dominated by oak, red maple, black cherry, sugar maple (*Acer*

*saccharum*) and hemlock. Albright et al. (2017) found that both stand age by percent and area are currently highest within the late successional stages with 29% within the 61–80-year class and 28% within the 81-100-year class. Also, 67% of forestlands are considered as having large diameter stands (hardwoods  $\geq 11$ " dbh and softwoods  $\geq 9$ " dbh) with the majority moderate to fully stocked (35-100%). Average annual mortality rate for Pennsylvania trees was 0.9% during this study, with lowest rates in the northcentral region. Health risks for today's forests include disease, insects, invasive plant competition, herbivory, and fragmentation. Impacts from these stressors have contributed towards the shift in composition and lower regeneration of the forest. Fortunately, managers on public lands have developed plans to address many of these issues through critical partnerships (Johnson et al. 2014, 2016), whether that's managing disease and forest pests through pesticide application, reducing fuel load and increasing regeneration for fire dependent species through prescribed fire (DCNR 2020), or reducing herbivory through increased deer harvest (Rosenberry et al. 2009).

**Predictive Climate and Forest Composition Models** – An important part of any assessment of this magnitude is understanding how things may change in light of past and current trends. Predicting the future is a challenging, if not impossible, proposition, but managers can take what information is available and draw conclusions on differing potential outcomes. One way this is commonly achieved is through theoretical statistical modeling. To quote the late George E. P. Box, an honored statistician, "All models are wrong, but some are useful." The last decade has seen a large volume of models predicting changes in climate as well as how this may affect characteristics of the landscape including forest composition. Several papers speak specifically to marten within their ranges throughout the country predicting both range expansion (Baltensperger et al. 2017) as well as contraction (Wasserman et al. 2012).

On a region scale (central-eastern North

America), Notaro et al. (2014) predicted a decline in snowfall, delayed onset of snow season, reduced persistence of snowpack, and less common but more intense snow events within the next century. Research focusing on the northern Appalachian Mountain range, specifically in regards to marten and lynx impact, predicted a 40% decline in marten populations by 2055 (Carroll 2007). In contrast to a declining snowfall model, albeit on a specific regional scale, Burnett et al. (2003) predicted increasing lake-effect snowfall on the leeward side of the Great Lakes, which would include the northwestern portion of Pennsylvania. Specific to the mid-Atlantic region, Butler-Leopold et al. (2018) predicted increasing temperature and precipitation as well as more extreme temperature shoulders on the year. This could potentially lead to an increase in intensive wildfire, tree mortality, forest pests and invasive species. An overall loss of forest land (10%) is predicted within the state within the next 50 years (Albright et al. 2017). Forest composition within the Commonwealth is predicted to shift with declines for species such as black cherry, maples, American beech and eastern hemlock, while oak species, hickory and black gum will expand their range (UCS 2008, Albright et al. 2017, Butler-Leopold et al. 2018). For martens in New England, as well as other locations within their southern range, potential for a warming climate to increase interspecific competition (Jensen and Humphries 2019, Pauli et al. 2022) as well as reduce gene flow among populations has also been predicted (Aylward et al. 2020).

Certainly, according to predictions, the outlook of forests and climate within Pennsylvania, and the greater mid-Atlantic region, will change, providing both positive and negative impacts to our current suite of species. This is crucial to keep in mind when assessing feasibility of a species reintroduction. It is also important to note that most of the research cited within this section provides caveats that read "...scenarios should be interpreted cautiously" (Carroll 2007) or "These studies suggest inaccurate modeling in areas with complex topography and rapid elevation change" (Butler-



Leopold et al. 2018). Albright et al. (2017) said it best in that "...predictions are future possibilities, not future truths."

## **Marten Habitat Assessment in Pennsylvania**

**Habitat Modeling** - The International Union for Conservation of Nature (IUCN) guidelines for reintroduction (IUCN/SSC 2013) stress the importance of ensuring that the cause of previous extinction has since been identified and rectified. In the case of the marten, ensuring that habitat exists within the Commonwealth is perhaps the most important aspect of this feasibility assessment. Understanding that habitat loss was the primary cause of extirpation for this species, it's imperative that managers properly assess current habitat conditions, including quantity, quality, and connectivity. Much of Pennsylvania's forest has regrown, and age classes within many public lands are well within the late-succession stage (61-100 years), soon approaching old growth (Albright et al. 2017). Note that age class may not always represent suitable marten habitat in complexity which is highly dependent on past management practices. It's also critical to mention that climatic conditions and how they affected composition may have been different prior to extirpation. Modeling habitat across large landscapes provides many challenges, but with advances in remote sensing technology such as airborne Light Detection and Ranging (LiDAR; Vierling et al. 2008), satellite imagery, and other detailed imaging software, there has not been a better time to combine the available resources and use this tool for determining habitat suitability.

Several non-spatial (not using Geographic Information Systems) habitat models have been developed for marten (Allen 1984, Bowman and Robitaille 2005, Fecske et al. 2002). Multiple spatially driven models have also been developed (Schulz and Joyce 1992, Kirk and Zielinski 2009, Rustigian-Romsos and Spencer 2010) with some models specific to reintroduction feasibility (MFWP 2020). Joyce (2018) proved that high pulse LiDAR

can measure fine scale habitat structure, such as coarse woody debris, and brought to light the potential of this technology for use in modeling for structural complexity.

Of all the habitat suitability models referenced within the large majority of marten habitat related literature, Arthur Allen's Habitat Suitability Index (HSI) Model developed in 1984 has been tested across multiple study areas and appears to describe marten habitat well. This model is effective because it can be used across a wide variety of locations throughout the marten's range. It has proved it is still applicable today, even competing with more modern models (Bowman and Robitaille 2005). Its limitation is the requirement of coarse woody debris, and this is a difficult category to measure. We decided to utilize the basic structure of this model to develop an HSI model that could use available spatial information to drive a geospatial model.

We originally selected 5 categories for analysis to include Land Cover, Snow Cover, Percent Canopy Cover, Stand Age, and Coarse Woody Debris. Land Cover data was used to look at forest type (coniferous, deciduous, mixed, etc.) and drew from the National Land Cover Database (USGS 2019). Snow cover data used came from the National Weather Service (NOAA 2021) and was given specific values for annual snowfall attributes averaged over the past 30 years. Percent Canopy Cover data came from the LANDFIRE database (USDA/USFWS 2022) and was assigned 5 categorical values. Tree Height data also came from LANDFIRE and was used as a surrogate for stand age (Bowman and Robitaille 2005, Maltamo et al. 2020, Xu et al. 2018, Racine et al. 2014) due to the extensive scale of the model. It also had 5 attributes of values. It should be noted that tree height is not always an indicator of stand age, particularly within mixed stands. This can also hold true for high elevation, xeric ridgetop sites with poor soil quality (Smith et al. 1997). We did attempt to incorporate Coarse Woody Debris, but unfortunately, we were not able to do so on the multi-state scale this model

was developed for. Although LiDAR data exists for the study area, there are concerns about the pulse rate accurately depicting ground cover (M. J. Joyce, University of Minnesota, pers. comm.), lack of GIS methods for this process, and lack of time and resources to complete the necessary processes to compute this layer (Joyce et al. 2019).

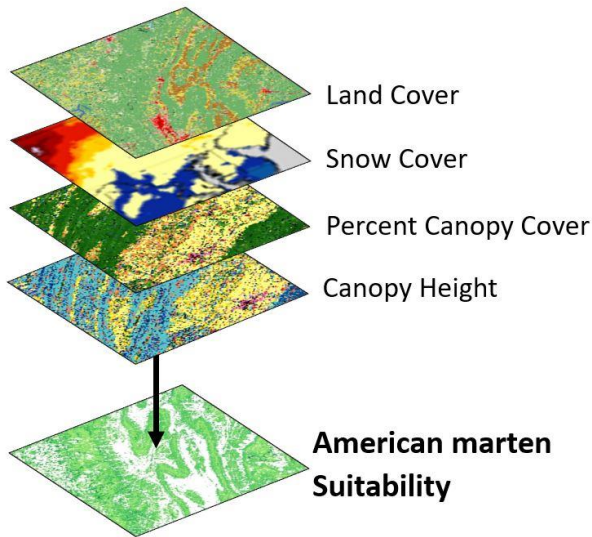


Figure 7. Categories used to develop American marten suitability model. E. Kerstetter 2022.

Attributes within each of the 4 categories’ raster datasets (Fig. 7) were reclassified with the original cell value changed to the corresponding HSI value with a range from 0 to 100. The reclassified raster datasets were added together to determine the final suitability value with a value of 400 being the highest suitability. Any cell with a HSI value of 0 was excluded. Focal statistics (ESRI 2022), a method of averaging surrounding cells, was then used on the final suitability raster to determine the mean suitability within the average home range of a marten (8.37 km<sup>2</sup>; derived from historical averages from 5 projects in MI, MN, NY and WI). A moving window with a radius of 1,631 m within the averaging process using the neighborhood circle method. This process determined specific areas that might be of high value. Public lands were also overlaid across the map to determine where optimal habitat coincided. We based our study area on nearest known populations of martens with Maine, Michigan, New Hampshire, New York, and Vermont included with Pennsylvania

in order to test the model against existing populations (Fig. 8).

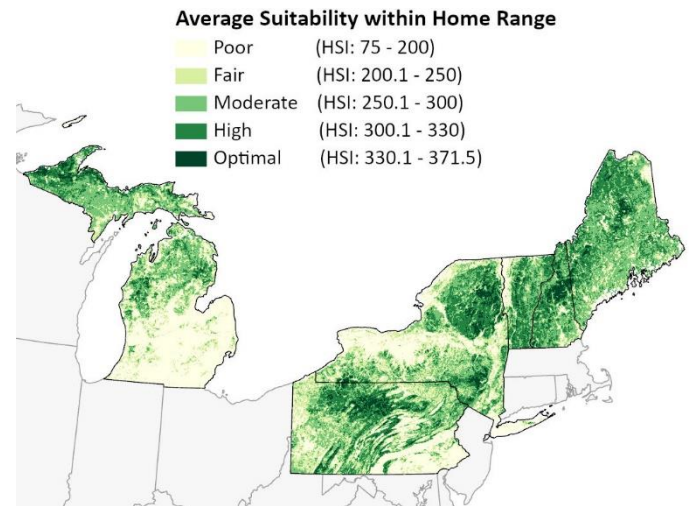


Figure 8. American marten habitat suitability across study area. E. Kerstetter 2022.

Finally, this model was tested and ground-truthed using known locations of marten within the study area utilizing two methods (Fig. 9). ‘Research’ grade American marten observations through iNaturalist (iNaturalist contributors 2022) were exported and overlapped with the focal statistic HSI layer (figure 9). The iNaturalist points were given the HSI value for the corresponding raster cell at each point. Values were

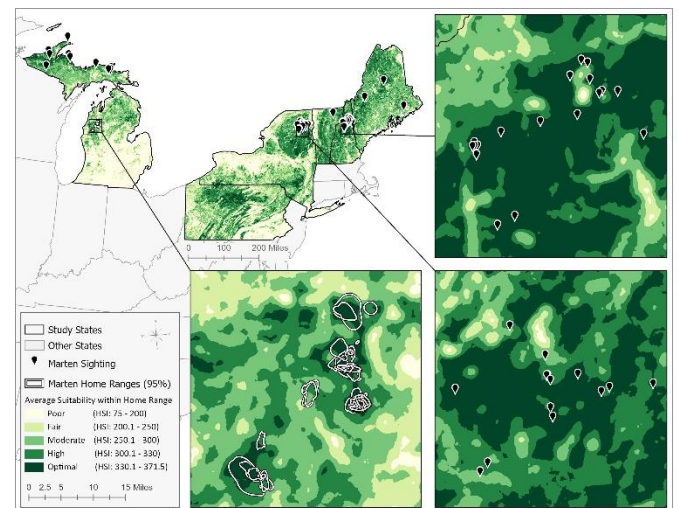


Figure 9. Locations of known marten and suitability used to test model. E. Kerstetter 2022, Boundary files from USCB 2021.

then averaged across samples to determine overall average of HSI across the study area. The other

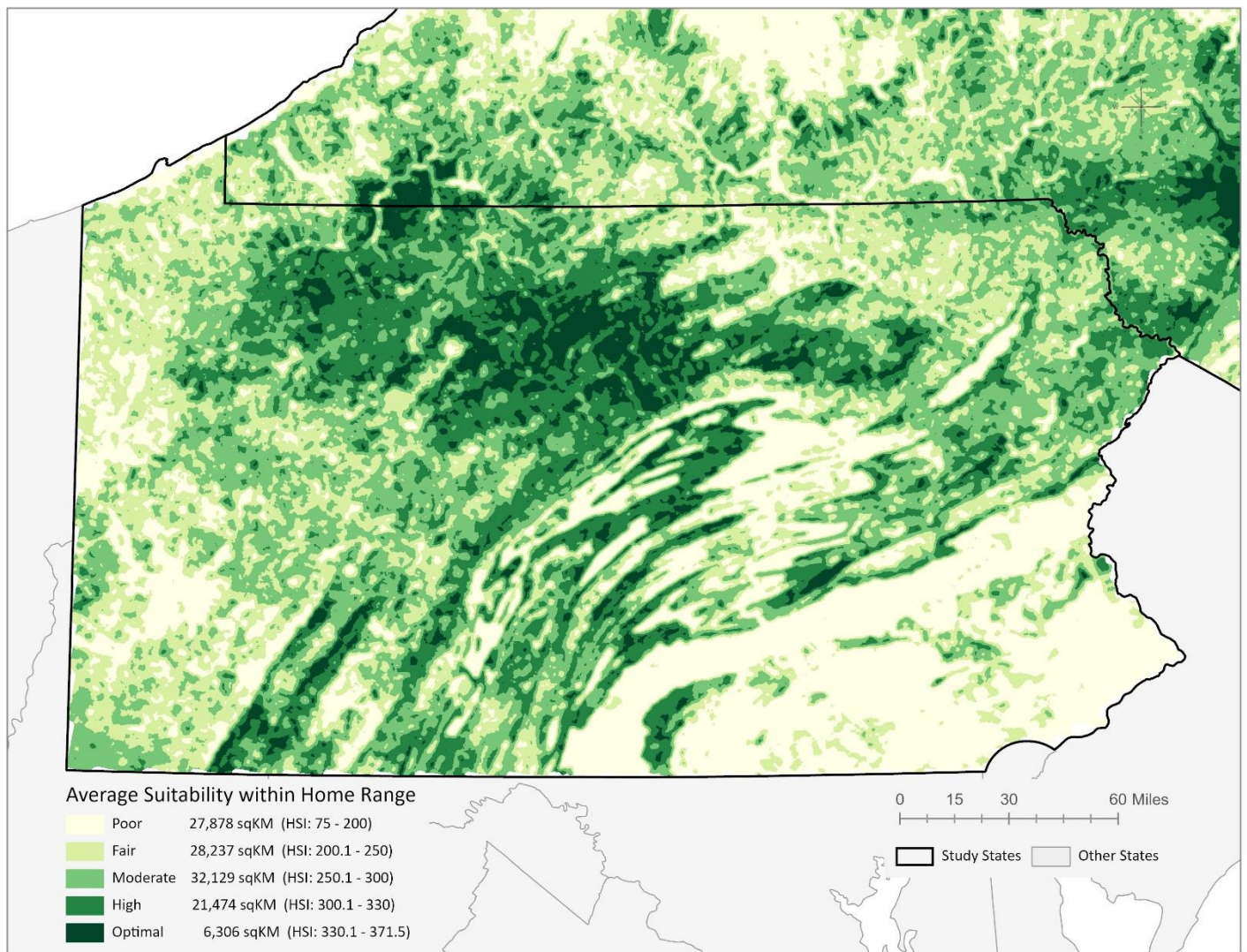


Figure 10. American marten habitat suitability model results for Pennsylvania. E. Kerstetter 2002.

method to determine suitability thresholds was using home range data from known populations within the northern Lower Peninsula of Michigan (A. M. Kujawa, LRBOI, unpublished data). Twenty-six home ranges, estimated at 95% fixed kernel density, were analyzed by averaging each 30 m<sup>2</sup> HSI cell within the home ranges prior to running the focal statistic. This result yielded an average HSI within each of the polygon home ranges. The HSI values for each home range were averaged to determine the average HSI value within this study area.

Home range HSI values were then averaged to find an overall average HSI value for the project area. Values for both HSI estimation methods were averaged to obtain overall thresholds for ranking

suitability (Appendix. 3).

Results show that Pennsylvania does indeed have comparable habitat for the American marten to other states with extant marten populations (Fig. 10 see page 18) with the large majority within the northern tier within what would be considered their historical range. Most optimal habitat falls within public land boundaries (Fig. 11), which are a combination of National Forest, State Forest, and State Game Lands. Not only is there high-quality habitat in large measure, but there is also good connectivity within this area. Our model identified habitat within other parts of the state such as the Laurel Highlands and Ridge and Valley sections, however, fragmentation by non-forest land uses is a concern with many of these areas.

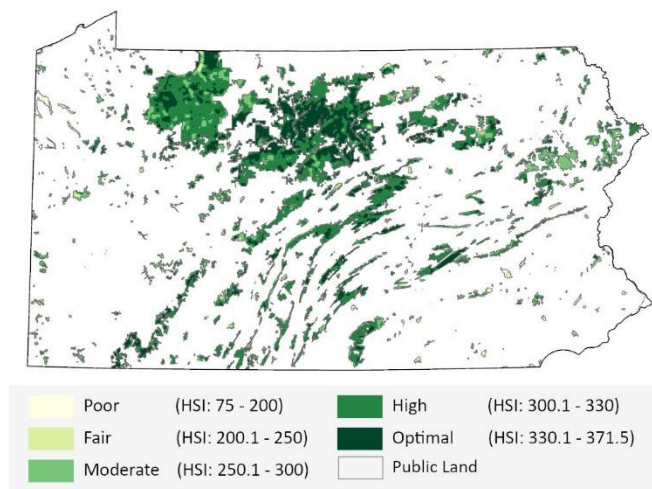


Figure 11. Suitable American marten habitat within public lands. E. Kerstetter 2022.

Revisiting the MVP suggested by Slough (1994) based on research from Strickland et al. (1982) of requiring a contiguous area of 42-125 km<sup>2</sup> to support a stable population consisting of 50 individuals, Pennsylvania meets those requirements. After analysis, 4,427.3 km<sup>2</sup> of the 6,306 km<sup>2</sup> of Optimal habitat and 24,719 km<sup>2</sup> of the 27,780 km<sup>2</sup> of Optimal and High combined is considered contiguous when analyzed at the threshold of 42 km<sup>2</sup> and above. Taking these values, dividing by 42 and multiplying by 50 (stable population) gives us a rough estimate of how many martens Pennsylvania could potentially support based on habitat suitability modeling results.

There are potential limitations to this model, being that equal weighting of all categories has the potential to over-estimate suitable habitat. Structural complexity, which is critical to marten, is extremely difficult to determine without having appropriate data on coarse woody debris. Finally, this model does not account for climatic conditions or resulting abiotic-productivity-intraguild interactions or relationships that ultimately dictate the presence and persistence of marten populations. These interactions will be addressed further on within this document.

**Field Assessment** – In 2021, the Pennsylvania Marten Reintroduction Assessment Working Group decided to invite American marten specialists to Pennsylvania from across the northeast and upper

mid-west to tour and provide feedback concerning Pennsylvania’s current state of habitat suitability for marten. Unfortunately, due to the COVID pandemic, restricted travel, and a relatively short timeline, only 4 biologists representing Michigan and Minnesota were able to attend, but their combined experience paired with a strong knowledge base of marten life history and habitat needs proved invaluable during their time in the Commonwealth. This field assessment occurred over three days (1-3 November 2021), with the intention of focusing on Pennsylvania’s northern tier (i.e., High Allegheny Plateau ecoregion), and the variety of forested habitat types it exhibits. The tour started within the Allegheny National Forest (ANF) Marienville Ranger Station, where we met with representatives from the U. S. Forest Service, Pennsylvania Game Commission (PGC) northwest region biologists, and members of the Working Group who represent the Pennsylvania Department of Conservation and Natural Resources (DCNR) as well as two bureaus within PGC (Wildlife Habitat Management and Wildlife Management).

From ANF, the tour continued eastward along Route 6, traversing what is largely privately held forest before passing through Susquehannock State Forest and arriving at State Game Lands (SGL) 208. Here, the team met with a PGC land manager, wildlife management supervisor, geospatial specialist, and forester, as well as a DCNR forester from the local district. Stops included a timber management area on SGL 208 and a late succession drainage area on Tioga State Forest. After spending the night in Williamsport, the team toured the Loyalsock State Forest, meeting with DCNR district managers and foresters, and then traveled through Ricketts Glen State Park and State Game Lands 13 before arriving at State Game Lands 57 (Fig. 12), where the team met with PGC land managers, biologists, game wardens, and senior staff. All told, this tour covered 20 counties traveling close to 600 miles through a large portion of Pennsylvania’s northern forested areas. This also allowed for a diversity of partner agency personnel to ask questions, raise concerns, and hear directly from



Figure 12. The assessment team pauses for a group photo at State Game Lands 57. T. Graziano 2021.

experts in the field of marten ecology and marten reintroduction.

Overall impressions from species experts were extremely positive. The primary takeaway messages were (M. J. Joyce, University of Minnesota, pers. comm.):

- There appears to be an abundance of adequate ground complexity which is critical resting and foraging habitat as well as access to the subnivean layer over winter.
- There appeared to be an abundance of adequate cavities suitable to martens for both resting and denning sites.
- There is adequate high canopy cover, appropriate for marten habitat.
- Both conifer and mixed stands were of high quality for marten at all elevations with hemlock and white pine, the predominant conifer species.
- The forested landscape has high overall connectivity for marten with minimal fragmentation from rural development, harvest, roads, and energy development.
- Based on habitat complexity and historic local research, prey abundance and diversity should be adequate for marten.

Reviewers also provided several recommendations. Concerning the habitat model, accounting for annual snowfall and persistence would be key to assessing the subnivean potential, as well as analyzing the

habitat quality at the scale of home range. Primary concern focused on intraguild and interspecific competition, mainly between marten, fisher, and bobcat. They suggested that snow depth might be an important factor in reducing potential conflict, but also noted that fisher and marten co-occur throughout their range in Minnesota and Michigan's Upper Peninsula. Other concerns centered on future climate unknowns and how that may affect forest composition and structure. None were overly concerned with potential negative impacts to possible prey species of conservation citing their generalist diet. All told, these experts were very pleased with habitat quantity, quality, and connectivity and on several occasions remarked that specific locations possessed higher quality habitat than some occupied ranges within their own states.

## Public Opinion

Successful wildlife management not only relies on sound biological methodology and data, but also considering social aspects. As the state agency responsible for the management of 480 species of wild birds and mammals in Pennsylvania, held in trust for the citizens of this state, it is critical we gauge interest or support for such a project. To do that, the Center for Survey Research (CSR) at Penn State was contracted, as an unbiased third party, to administer a survey statewide. The survey instrument used was a Qualtrics™ online survey. The CSR contracted Marketing Systems Group to recruit respondents from across the state. The survey was designed to eliminate bias towards location, age, or gender. Respondents were adults who choose to participate, and not selected at random. Two questions concerning American marten reintroduction were included within a larger survey. (See Appendix 4)

All told, 72,707 individuals were invited to participate, with a total of 1,047 respondents completing the survey and used for analysis. Participation rate was 1.8% and survey margin of error was +/-3.0% with a 95% confidence interval. Looking at the 3 most relevant categories (gender,

age, and hunting participation) and their averages, most respondents had not heard of the American marten (66%), with females, aged 18-34, and non-hunters having less familiarity with marten. **Combining the oppose and support metrics, overall support averaged 92.4% across categories and opposed averaged 7.6%.** These did not vary significantly across or within categories. For further results, see Appendix 4.

## Considerations for Success

Another critical step in conducting a feasibility assessment is identifying risk or potential impacts to other species, impacts from climate, or impacts to marten themselves. Reintroduction of a missing piece to the ecosystem can possibly create changes that are difficult to anticipate, so ensuring these changes are considered is important when making management decisions on this scale. Concerns within Pennsylvania likely center around how marten could negatively impact a variety of both game and non-game species, how other predators might negatively impact reintroduced marten and their survival, and how an unknown change in climate could affect marten long-term survival within the state. Several other concerns have been identified throughout the review process as well including incidental harvest and long-term genetic viability.

**Impacts to Other Species** - With any predator species reintroduction, there is much trepidation from both wildlife managers as well as the public with concern to how this might impact their species or community of interest (Serfass et al. 2003). Some modeling work has been done for large, keystone predators such as wolves (Baker et al. 2016) to predict changes, but little for species such as the marten. Concerns considering direct mortality to other species should first be addressed through prior diet studies to determine if any one species, or group of species is at risk. A total of 664 Species of Greatest Conservation Need (SGCN) have been identified within the *2015-2025 Pennsylvania Wildlife Action Plan* (PGC-PFBC 2015), with 68%

invertebrates, 14% birds, 10% fish, 3% reptiles, 3% mammals, and 2% amphibians.

Of these species that share a similar habitat and space use type, a variety of birds, several mammals, and a select few reptiles and amphibians have the potential to be impacted by marten reintroduction. Understanding how marten could impact invertebrates is difficult to measure, particularly with the lack of research, but we do know that insects can make up a significant portion of their diet (17.8% FO) depending on time of year. Avian and mammalian species identified as potential species of impact (PSOI) from this list are the northern goshawk, blackpoll warbler (*Dendroica striata*), yellow-bellied flycatcher (*Empidonax flaviventris*), ruffed grouse, northern flying squirrel (*Glaucomys sabrinus macrotis*), Allegheny woodrat (*Neotoma magister*), Appalachian cottontail (*Sylvilagus obscurus*), and several shrew species (*Sorex spp.*). Additional species that are not included within the Action Plan that have been identified as PSOI are snowshoe hare, and wild turkey (*Meleagris gallipavos*). There may be other species that a variety of groups and individuals might also consider as PSOI.

The Western Pennsylvania Conservancy was contracted to provide a spatial analysis of SGCN, identifying occurrence locations (WPC 2022). The six species that were targeted were goshawk, grouse, woodrat, northern flying squirrel, Appalachian cottontail, and rock vole (*Microtus chrotorrhinus*). Within the designated study area, based on available habitat, they detected 3,441 occurrence features throughout. These data were derived from the Conservation Opportunity Area Tool (PGC-PFBC 2019) and includes occurrences from a variety of sources from 1983 – 2021. These data can provide important information on both individual locations of PSOI as well as high-density areas. The report recommends further evaluation of highly sensitive occurrence areas as well as long-term monitoring of these in the case of a reintroduction effort. For the full report and findings please see Appendix 2.

It is important to again stress the fact that

martens are highly adaptive dietary generalists (Zhou et al. 2011). No research has pointed towards selectivity, only an opportunistic approach to hunting and feeding within a relatively large home range (see *Diet* section above). Martens don't control prey species, but rather in some cases are controlled by fluctuations in prey species (Thompson and Colgan 1987, Fryxell 1999). This large diversity of prey has been well documented through an extensive sample of diet research from across their range in North America (Fig. 13). When diet composition is broken into 7 basic categories, it's easy to identify not only how diverse their diet is, but what prey group makes up the large majority of their diet. Small mammals (68.2% FO) are by far and away the highest, while the 'other' (23.3% FO) category, which includes insects, cervid carrion, fish, amphibians, reptiles and a species of western woodrat is second, plants (21.7% FO) are third, birds (12.3% FO) are fourth, squirrels (11.5% FO) fifth, lagomorphs (9.3% FO) sixth, and mustelids (2.7% FO) are seventh. Of course, without having Pennsylvania specific data we can only speculate that this would remain true here. We can, however, examine the fisher in Pennsylvania, and find a similar diversity of prey items. Diet research from McNeil et al. (2017) found only one of the previously listed PSOI, that being the Allegheny woodrat (cottontail spp. are not separated between Appalachian and eastern), within stomach contents. We can assume that a smaller mustelid species that shares a significant portion of diet range with fisher would have a similar range of diet.

Species such as ruffed grouse and snowshoe hare are currently experiencing declines within Pennsylvania due to disease (Stauffer et al. 2018, Nemeth 2021) and habitat loss (Diefenbach et al. 2016, Dessecker and McAuley 2001). Wild turkey declines within the state are currently being researched, however, turkey have not been identified within diet research for marten. The Allegheny woodrat also struggles with habitat loss (Balcom and Yahner 1996) and disease threats (LoGiudice 2000), while many other avian species considered SGCN face continued habitat loss as well as pesticide concerns (Rosenberg et al. 2019).

With very few records of breeding northern goshawk within the state, there has been some concern voiced of a threat from marten reintroduction. Goshawk are considered one of the primary avian predators for the marten (Bull and Heater 2001, Squires 2000: see *Mortality* section). One specific instance of a marten predated a goshawk could be found in the literature (Paragi and Wholecheese 1994). Personal communications with a researcher conducting telemetry work with marten in Michigan found a telemetry collar from a marten underneath the predated nest of a goshawk (R. Sanders, MI DNR, pers. comm.). Much could be assumed from this instance such as marten predation of a nest and goshawk predation of a marten. In an evaluation on the decline of goshawks, Reynolds et al. (2006) noted that marten are potential predators for the species, however, predation is unlikely a major contributing factor to population dynamics, instead pointing towards forest structure and food availability.

Based on extensive prior diet research (Fig. 13), marten predation on these 'rare' species having low abundance should be minimal and have little to no impact on overall species populations. It is recommended, however, that pre- and post-release monitoring of PSOI species within release areas be conducted to measure any significant impact that may occur. It's important to note there are many examples of locations where PSOI species ranges overlap with marten and populations of both are healthy and abundant. A project such as this has the potential to benefit this suite of species that share similar habitat through an influx of resources towards improving a structurally diverse habitat on the landscape, increased education, and monitoring of a community based on a single umbrella or flagship species such as the marten (Roberge and Angelstam 2004). Forest heterogeneity (described in *Interspecific Competition*) having structural complexity benefit many of the PSOI species identified, and efforts such as Dynamic Forest Restoration Blocks (MDNR 2022, RGS 2022) being promoted by the Dynamic Forest Partnership and the Ruffed Grouse Society fit well into the habitat needs

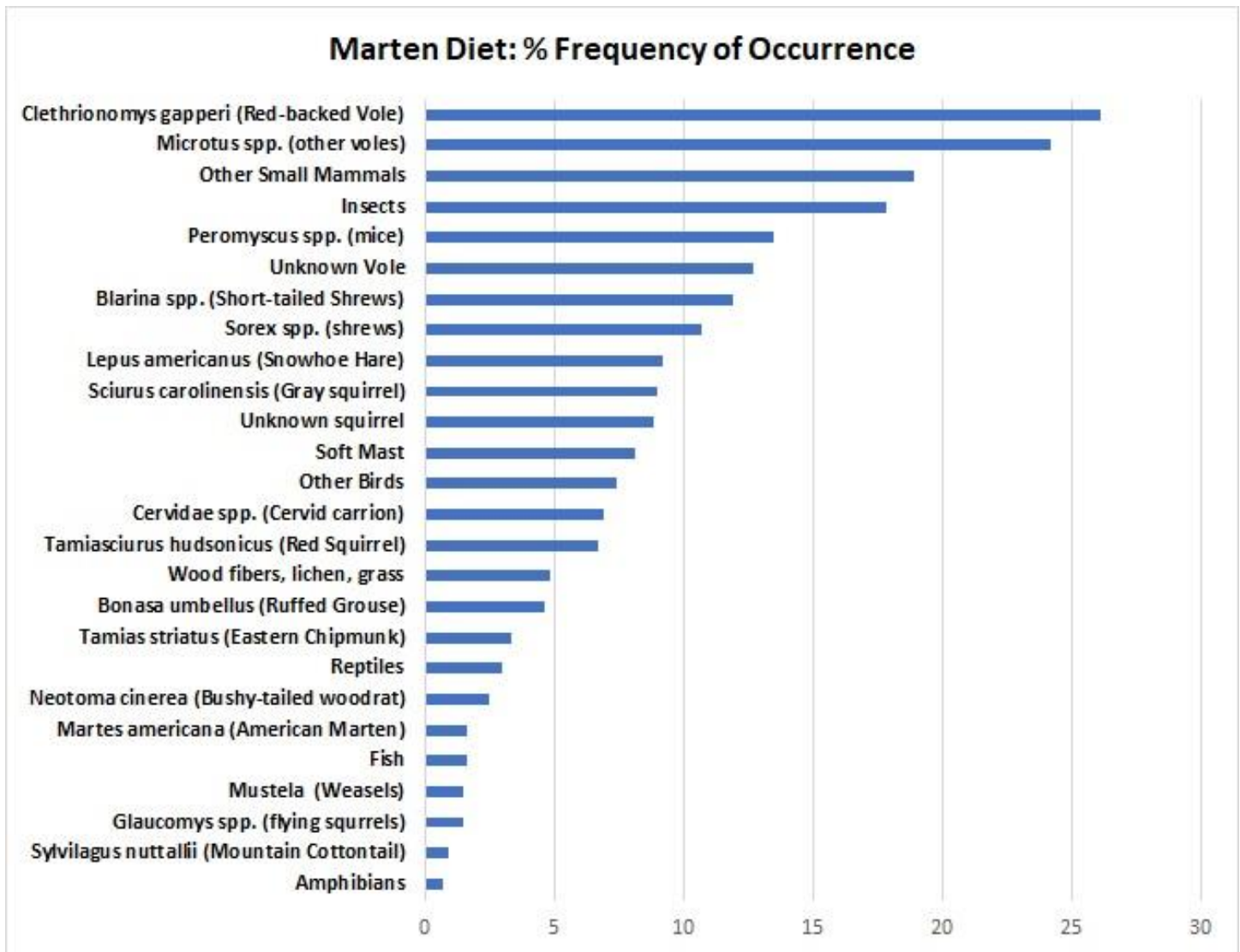


Figure 13. An average of 13 American marten diet studies throughout the marten range by % frequency of occurrence and species. See Appendix 1 for additional details.

of marten by providing these important characteristics.

**Climate Impacts** – The impact of climate and its potential for change over time is an important consideration for how a species reintroduction may succeed in future years. Review of literature concerning climate impacts, specifically for marten, provided mixed results on whether they would be positive or negative with predictions for snowfall changes variable within the state; while the future of forest composition within Pennsylvania could see both losses and gains of important species for marten habitat (see *Predictive Climate and Forest Composition Models* section). Many of the large-

scale, Northeast region predictions, unfortunately, spell challenge for most current communities, including marten within their southern ranges (Pauli et al. 2022, Lawler et al. 2012).

Fortunately, it appears that the historic range of marten within Pennsylvania (and the current area of existing habitat), the northern tier, possesses some attributes that may allow this area to persist as landscapes with suitable conditions for marten even with predictions of changing snowfall and forest composition. With increased variation in topography at higher elevations (Jensen and Humphries 2019), what is considered ‘mountainous refugia’ (Carroll 2007), and the potential for increased snowfall



within northwestern Pennsylvania from lake effect (Burnett et al. 2003), some biotic and abiotic conditions may help insulate negative impacts to marten within the Commonwealth. There is also some evidence that both passive (reduced fragmentation and overstory removal: Steventon and Daust 2009) and active habitat management strategies (anthropogenic refugia development: Morelli et al. 2012, Zielinski et al. 2017) can be employed. The Resilient Land Mapping Tool from The Nature Conservancy shows strong resilience (climatic diversity that increases persistence and retention of biodiversity), flow (ability for populations to move in response to changing climate) and biodiversity value overlapping current habitat for martens in Pennsylvania (Anderson et al. 2016, Fig. 14).

Research from California focusing on niche overlap between marten (*M. americana* and *M. caurina*) and fisher found that martens were expanding their range into lower elevations with warmer temperatures and reduced snowpack (Zielinski et al. 2017), potentially highlighting adaptability to a warmer climate. Although there is much unknown behind how climate might change, the severity of change, and its impact on the landscape, managers should embrace adaptive management strategies that promote continued habitat diversity, structural complexity, and

connectivity.

**Interspecific Competition** – The relationship between marten and other predator species that share both diet and space, in particular the fisher, is one of the most widely researched aspects of marten biology besides habitat (Pauli et al. 2022, Jensen and Humphries 2017, Zielinski et al. 2017, Manlick et al. 2017, Fisher et al. 2013, McCann 2011). Regardless of a variety of research, this exact relationship continues to prove somewhat elusive (see *Interspecific Competition and Coexistence* section). It is, however, a major concern for a reintroduction project within Pennsylvania as competitor species such as fisher, bobcat and coyote continue to show stable to increasing populations – over the long-term (Keller 2021). There are several factors identified within literature that appear to allow for sympatry and minimize interspecific competition.

Size of various food items can allow for sympatry through diet partitioning, with larger competitors preferring larger prey, especially during winter, such as deer carrion (Raine 1981, Jensen and Humphries 2019 Pauli et al. 2022). Each year, approximately 30% of white-tailed deer mortalities do not involve deer hunting (Rosenberry et al. 2009). The 300,000 to 400,000 white-tailed deer taken by deer hunters each year (PGC 2022) represent the remaining 70% of mortalities. As a result, tens of thousands of potential deer carcasses are available to predators/scavengers throughout Pennsylvania each year. Prey abundance and diversity is high within the state (WPC 2022), providing opportunity for diet partitioning throughout the year and lessening competition for a specific prey species.

Another important factor is the presence of a subnivean space throughout winter from which marten can hunt with very little competition (Buskirk and Powell 1994) from larger predators, as well as find safe refugia for resting locations (Joyce et al. 2017, Krohn et al. 1995, 1997, 2005; Raine 1981). With minimum snow depth for subnivean establishment at 10 cm (Thompson et al. 2018), Pennsylvania’s marten habitat within the northern tier, paired with variability of elevation and

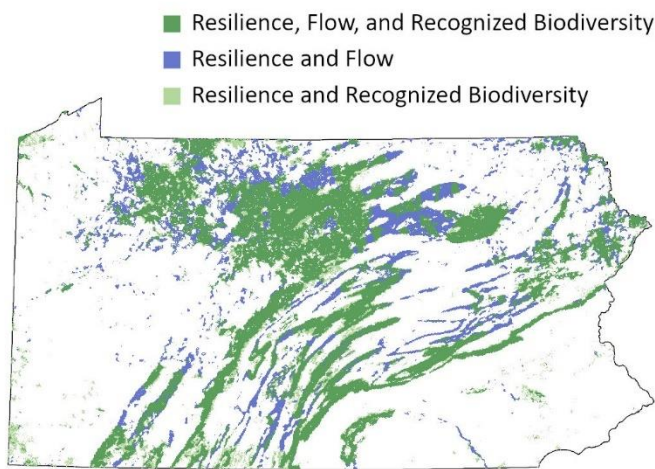


Figure 14. Resilience, flow, and recognized biodiversity of Pennsylvania. E. Kerstetter 2022 (Data from Anderson et al. 2016).

topography, and matched with this region’s average annual snowfall ranging from 76-280 cm (NOAA 2022), should provide adequate subnivean space for marten throughout the winter. Further investigation into snowpack will help managers determine best locations for release.

The concept of habitat and spatial heterogeneity has also been identified as an important factor for coexistence (Fisher et al. 2013, Manlick et al. 2020, Pauli et al. 2022). Marten habitat identified in Pennsylvania falls within very diverse, and contiguous sections of forest that have extremely low anthropogenic development and fragmentation (Albright et al. 2017). This area also occurs within a region of higher elevation and variation in topography, two additional factors that can contribute to niche or habitat partitioning between competitors (Pauli et al. 2022, Zielinski et al. 2017, Rosenzweig 1966, Raine 1981). Pauli et al. (2022) postulate that where segregation occurs, densities for both species increase, while areas of coexistence see lower marten densities. This is an important aspect to keep in mind, that should marten be reintroduced, they may remain at a lower density but at a self-sustaining level as is seen in other parts of the range. Although Pennsylvania would be considered on the very southern range of marten within the east, many of the factors that contribute to increased interspecific competition may not be as applicable due to the current biotic and abiotic conditions, providing for an increase in the likelihood of successful reintroduction.

### **Other Concerns**

Concern from incidental trapping has been expressed from experts throughout the Mid-West and Northeast where some reintroduction efforts have experienced this. Although valid, due to the susceptibility of marten to trapping, unlike these states, Pennsylvania does not allow the use of conibears outside of an established watercourse, waterway, marsh, pond, or dam (PGA 1986b). This would not preclude marten from becoming captured within foothold traps set on land for a variety of other species but would potentially allow any captured marten to be released

unharmful if no serious damage occurs while in a trap. An important aspect of this concern will be working with trappers to educate on the importance of selectivity and avoidance within areas that marten would inhabit.

Another valid concern from experts is population resilience and persistence, specifically maintaining genetic heterozygosity over the long-term. Although a reintroduction in Pennsylvania would be considered an ‘isolated’ population on the southern extent of their range within the east (Aylward et al. 2020), there are currently many other examples of ‘isolated’ self-sustaining populations on a much smaller scale of available habitat than what the Commonwealth can provide. States such as South Dakota (Fecske 2003), Montana (MFWP 2020), and Michigan (Gehring et al. 2019) have all conducted successful reintroduction efforts creating ‘isolated’ populations. Martens continue to persist on islands within Lake Superior (Smith et al. 2021) and the Gulf of Alaska (Small et al. 2002) with little to no genetic ingress/egress. Regardless, genetic monitoring should play an important role throughout the process of a reintroduction, from how and where animals are sourced, to what genetic diversity looks like into the future of a population.

## **Translocation and Reintroduction**

**Considerations for Reintroduction** - Translocation, the intentional movement of a species from one location to another, has been conducted throughout the world over a broad spectrum of species. The three common objectives of translocation are to establish, reestablish or augment a species population (Griffith et al. 1989). International Union for Conservation of Nature/Species Survival Commission (IUCN/SSC) (2013) defines reintroduction as “the intentional movement and release of an organism inside its indigenous range from which it has disappeared.” Regarding what characterizes a successful translocation or reintroduction effort, the primary goal is a self-sustaining wild population (Seddon et al. 2014, Griffith et al. 1989). Prior to conducting a

reintroduction effort, a variety of factors should be considered. Defining the need for a project of this scope is critical. Developing a feasibility assessment that encompasses pertinent biological and non-biological factors ensures that the decision is not made lightly or without thought. Biologically, this includes general life history information that can speak to how a species fits within the community as well as important habitat needs, general diet information, and climate considerations. Non-biologically, it is important to consider the social aspects of a reintroduction effort, specifically how this project might affect the surrounding community, stakeholder support, opposition from individuals and groups, economic impacts, and cultural considerations (IUCN/SSC 2013). A significant portion of a feasibility evaluation addresses proper risk assessment, to include disease/parasite risk to other extant species, risk to both potential prey species as well as competitors, risk to the translocated species welfare, and social risks as mentioned previously.

**A History of Reintroduction in Pennsylvania** – Pennsylvania has a robust historic record of successful species reintroduction efforts. Following post-settlement anthropogenic induced habitat loss, many species, primarily habitat specialists, were extirpated. What species remained were considered generalists or retreated into the remaining habitat that was largely inaccessible to humans. As forests regrew, water quality improved, and regulated harvest or protections were put into place. State agencies in partnership with universities, NGOs, and individuals began to pursue reintroduction as a tool to restore native species back to the Commonwealth. Culturally important game species such as white-tailed deer (*Odocoileus virginianus*) and wild turkey (*Meleagris gallopavo*) were some of the first to see reintroduction efforts, followed by Elk (*Cervus canadensis*). Bald eagles (*Haliaeetus leucocephalus*), peregrine falcons (*Falco peregrinus*), and osprey (*Pandion haliaetus*) all returned to the state through intensive reintroduction efforts following pesticide related declines (Kosack 1995). Aquatic species such as American eel

(*Anguilla rostrata*; Newhard et al 2021), northern riffleshell (*Epioblasma rangiana*), clubshell (*Pleurobema clava*; Tiemann et al. 2013) and invertebrates like the regal fritillary (*Speyeria idalia*; Becker 2016) have all seen successful population expansion through reintroduction or are in the midst of promising reintroduction efforts. Of all species groups, furbearers have seen extraordinary success within Pennsylvania through reintroduction. Beavers (*Castor canadensis*) were extirpated by the end of the 19<sup>th</sup> century as well as fisher, while river otter (*Lontra canadensis*) were driven to near extirpation during this time with very few individuals remaining in the isolated wetlands of the northeast region. Translocation projects beginning in the early 1900s for beaver, 1982-2004 for river otter, and mid 1990s for fisher, were all successful in returning these iconic species to the forests and waterways of the state (Kosack 1995). Today, many of these species continue to expand their ranges throughout Pennsylvania through dispersal into existing habitat. Currently, the Commission is working towards restoring bobwhite quail (*Colinus virginianus*) through habitat management and translocation efforts proving that this technique is still relevant for returning native species to the community. That's not to say that reintroduction has always been successful, but many past failures have been the result of no prior assessment, poorly established habitat, and a lack of planning.

**Marten Reintroduction Efforts** – American marten may be one of the most frequently translocated furbearing species to date. Powell et al. (2012) reported documenting 51 translocation efforts occurring from the early 1900s through 2010. These occurred within 9 U.S. states and 7 Canadian provinces (Fig. 2). Thirty-nine of these were reintroductions, which was one more than was reported by Slough in 1994. Since 2010, there has been at least one additional reintroduction in Montana, with first releases in 2020-2021 (MFWP 2020). Of the 39 reintroductions, 20 succeeded, 9 failed and 10 had uncertain outcomes (Powell et al. 2012). Since this time, the reintroduction project within the Green Mountains of Vermont has been

deemed a success (O'Brien et al. 2018), changing success rate to 54% and failure rate to 21% (25% unknown). With this original reintroduction project completed in 1991, it speaks to marten population resilience over time even at low density. Slough (1994) found that habitat quality of release sites as well as the number of animals released (>30) were primary contributing factors to success. Powell et al. (2012) used modeling of historic translocations to determine variables of success. This research found that success depended upon total number of animals (>60), total number of release sites (more is better), and number of females released (higher ratio of females). This bounty of prior effort provides great guidance and information on not only an assessment of feasibility, but also future reintroduction planning.

## Why Consider Reintroduction

Why consider reintroduction of American marten to Pennsylvania? Most prior reintroduction projects have cited the need to not only restore a native species that was extirpated, but to continue working to restore the overall ecological community to which marten were once an important part (Powell et al. 2012, Slough 1994). The idea of ecological restoration centers on attempts to return “community composition, ecosystem structure, and ecosystem processes” from a “degraded or damaged” ecosystem (Holl 2020). There are many motivations for this defined type of restoration, including conservation of biodiversity, both with species and habitat. Biological diversity describes not only species diversity, as is usually associated with the term, but genetic and ecosystem diversity as well (Tsioumani and Tsioumanis 2020). Often, we separate ourselves, from this idea of interconnectivity, but in reality, “biodiversity underpins human well-being and livelihoods” because we share this greater ecosystem with all life (Tsioumani and Tsioumanis 2020).

This idea of biological diversity ties directly into the political side of why considering reintroduction is important. The Convention on Biological Diversity (Broome 2010) is a worldwide initiative

aiming to reduce biodiversity loss and is a critical partnership across the globe of nations working together towards a common goal that affects everyone. The DCNR “manages state forests to provide habitats that support diverse, healthy populations of wildlife...” (DCNR 2016) as well as seeks to “restore or maintain diverse habitats and resilient ecosystems” (DCNR 2020), key tenets within their State Forest Resource Management Plan and Forest Action Plan. This very assessment is called upon under the Pennsylvania Game Commission’s own Strategic Plan (PGC 2020), under goal number one which states “Manage diverse and sustainable wildlife for current and future generations.” As stewards of the state’s natural resources, the DCNR and PGC are charged with both maintaining and increasing ecological diversity.

An additional reason for considering reintroduction is enhancing ecosystem processes (Holl 2020). An example of this is the marten’s propensity towards frugivory and the importance they play in seed dispersal for a variety of plant species (Willson 1993, Buskirk and Ruggiero 1994). The generalist nature of the marten’s diet can also act as a stabilizer for rodent populations (Anderson and Erlinge 1977) within the forest system. The importance of counteracting climate change through carbon storage (Cromsigt et al. 2018, Holl 2020) has been cited as another critical reason for the idea of ecosystem restoration, and marten preferred habitat lends itself to this concept. Marten have also proven to serve as an important ‘umbrella’ species, or a species that is representative of a specific ecosystem or suite of species that all benefit from the management for this single species (Caro 2010). Research from Maine (Mortelliti et al. 2022) found that by using marten as an umbrella for monitoring, they could detect population trends of 11 other species, including coyote, red squirrel (*Tamiascurus hudsonicus*), fisher, snowshoe hare, raccoon (*Procyon lotor*), short-tailed weasel (*Mustela erminea*), red fox, lynx (*Lynx canadensis*), moose (*Alces alces*) and others. This idea of using marten as an umbrella or even as a flagship species, either

singly or as part of a multi-species suite, as a conservation tool for a variety of other species and habitats is well vetted (Roberge and Angelstam 2004) and one that is being used within the Commonwealth currently with bobwhite quail (*Colinus virginianus*) reintroduction.

Economic benefits of wildlife can be very difficult to describe (Aylward 1992) due to the differing methods to which a dollar amount is assigned to a specific activity, species, habitat type or function. Historically, martens were an important furbearing species, and in states where population recovery was successful to the point of harvest, trapping opportunity has resumed and remained strong. Following fisher, beaver, elk, and otter reintroductions in Pennsylvania, managers were able to monitor populations and when they reached a specific threshold, provide consumptive use opportunity as well, which would be a similar consideration for marten if re-established. Kreye (2019) references the idea of both ecological and cultural services within the economic benefit construct. Ecosystem services tie directly into these economic benefits when it comes to the previously mentioned seed dispersal and considering what the cost of replacing that function through human resource might be.

A report on outdoor recreation spending in Pennsylvania by Theodore Roosevelt Conservation Partnership (2018) estimated over 98 million dollars in economic contributions in 2016, 4.3% of Pennsylvania gross domestic product for that year. This report considered both consumptive (i.e., hunting) as well as non-consumptive (i.e., wildlife watching) activities and estimated over 1.1 million wildlife watching participants. Reintroduction of an iconic forest dwelling species such as the marten could contribute to drawing even more people to Penn's woods and the continued growth of this important economic driver. Kreye (2019) combines ecological-supporting services and cultural value with the idea of cultural services. She describes three benefits that people receive from non-consumptive use of wildlife. The idea of *existence value*, knowing

an animal exists, *bequest value*, knowing that generations to come will have access to an animal, and *option value*, knowing the animal and its services are available into the future whether it is used or not. Actual dollar amounts relating to these concepts are seen through examples such as referendums for land preservation or donations towards specific species restoration projects (Kreye 2019).

It is important to also consider the cultural significance of wildlife and particularly the marten within this region. Pennsylvania has a rich indigenous people's history with many tribes inhabiting the region prior to the formation of the state itself. Tribes such as the Seneca, Shawnee, Susquehannock, Erie, Shawnee, Monongahela, and Delaware occupied various territories within the area and valued wildlife both spiritually as well as consumptively (Richter 1990). Today, there are no federal or state recognized tribal lands within Pennsylvania, but many native peoples still inhabit the Commonwealth. Marten have held special significance to a variety of indigenous peoples surrounding the Great Lakes (Sanders 2014, WDNR 2011, Dumyahn et al. 2007), often representing people groups or 'clans' (Fig. 15). The marten clan is often made up of hunters, scouts, and warriors, a reflection of the nature of the species. Legends and stories surrounding the marten are also important aspects of these native cultures (NLA 2020).

Finally, Pennsylvania agencies, and particularly those responsible for species groups, have set a long-standing precedence of returning extirpated species to the Commonwealth's waters, fields, and forests. This has occurred through a variety of partnerships with NGO's, academic institutions, federal agencies, public and private landowners, and volunteers. These efforts were often conducted during challenging conditions with scarce resources, mediocre habitat, and environmental degradation (Kosack 1995). Nevertheless, managers worked tirelessly towards success and thanks to those historic efforts, current, and future generations can once again hear the bugle of an elk on a crisp September morning outside of

Benezette, watch a peregrine falcon streak towards its prey at blinding speed over a field near Middle Creek, or watch a beaver silently slip into the misty, cool water of the Allegheny.



Figure 15. The American marten represented within indigenous artwork. Artwork by Mark Anthony Jacobson.

## Recommendations for Reintroduction

**Recommendation** - Considerations for the reintroduction of any species back onto the landscape is not something to be taken lightly. The purpose of this assessment is to provide biological and historical background on the American marten as well as consider reasons for a reintroduction, potential impacts of a reintroduction, and potential for success now and into the future. This assessment determined that American marten was a native species to Pennsylvania prior to European settlement that was extirpated through near statewide deforestation and unregulated harvest. Through changing land use, reforestation occurred and a current portion of

forested land within the northern tier of Pennsylvania is currently considered habitat for marten based on habitat modeling and expert opinion. Three major concerns were identified from previous reintroduction efforts, literature review, and expert communication. These include negative impacts to species of concern, future climatic impacts to marten persistence, and interspecific competition impacts on marten. Based on historic diet analysis, prey abundance estimates, habitat modeling, and assessment of Pennsylvania specific biotic and abiotic factors known to affect differing aspects of marten ecology, it is reasonable to believe that impact on other species and on marten are minimal and through adaptive management, future climatic challenges can be addressed. This isn't to say that there is no risk to such a decision or that there are not still many questions unanswered within the available literature. Proper risk management understands that there are many uncertainties, but biologic, social, economic, and cultural benefits are many for this project, and ostensibly outweigh perceived risks. American marten reintroduction to Pennsylvania is likely to succeed and should be considered as the next step in a long history of restorative conservation efforts within the Commonwealth.

**The Bureau of Wildlife Management, therefore, recommends that American marten be reintroduced to the state of Pennsylvania through deliberate planning and dedicated partnership.**

**Next Steps** – This assessment will be presented to the Pennsylvania Game Commission Board of Commissioners during their quarterly meeting in July 2022. At that time the board will consider the current assessment and recommendation. If the board decides not to move forward with the recommendation, no further action will be needed. If the board decides to accept the current recommendation, several important 'next steps' will need to take place. The first step would be developing an *American Marten Reintroduction and Management Plan: 2023-2033*. Strategic plan (PGC 2020) goal 1.3b states "If a plan is necessary, develop by June 30, 2023." This plan would focus on

important aspects of a project of this magnitude, including translocation, release locations, research and monitoring, information and education, cooperative partnerships, and long-term management. Translocation planning alone would focus on source populations, trap and transfer planning, and disease management among other things. During the drafting of this guiding document, partner engagement will be critical in selecting both release locations and source populations. Another important step during this time would be a public education campaign to begin bringing awareness and engagement to the project. Once a long-term, public reviewed, and BOC accepted plan has been approved, managers can begin to implement for the reintroduction of this iconic, native species.

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# Appendix 1. A comparison of 13 American marten diet studies showing percent frequency of occurrence.

	ON <sup>1</sup>	WI <sup>2</sup>	MI <sup>3</sup>	OR <sup>4</sup>	NB <sup>5</sup>	MI <sup>6</sup>	ME <sup>7</sup>	CA <sup>8</sup>	MT <sup>9</sup>	AK <sup>10</sup>	ID <sup>11</sup>	MB <sup>12</sup>	CO <sup>13</sup>	Avg.
<b>Small Mammals</b>	<b>68.0%</b>	<b>64.3%</b>	<b>77.9%</b>	<b>80.1%</b>	<b>46.2%</b>	<b>100.0%</b>	<b>87.1%</b>	<b>24.6%</b>	<b>60.3%</b>	<b>58.0%</b>	<b>100.0%</b>	<b>20.5%</b>	<b>100.0%</b>	<b>68.2%</b>
<i>Myodes gapperi</i> (Red-backed Vole)	30.5	15.7	34.2	24.6			38.4		20.5	58	36	8.4	81	26.1
<i>Microtus spp.</i> (other voles)	8.8			27.4	26.4	31	38.1	16.1	39.1		30	10.2		24.2
Unknown Vole				12.7										12.7
<i>Peromyscus spp.</i> (mice)	21.2	10	19.9	7.8	4	59	3.6	6.3	0.7		2			13.5
<i>Sorex spp.</i> (shrews)	3.6	38.6	7.4	4.7	15.8		7	2.2			1	1.9	42	10.7
<i>Blarina spp.</i> (Short-tailed Shrews)	1.3		16.4			18								11.9
Other Small Mammals	2.6			2.9		27					43			18.9
<b>Lagomorphs (Hare/Rabbits)</b>	<b>13.0%</b>	<b>1.4%</b>	<b>0.9%</b>	<b>2.4%</b>	<b>8.0%</b>		<b>1.7%</b>	<b>4.9%</b>	<b>2.9%</b>		<b>2.0%</b>	<b>58.9%</b>	<b>6.0%</b>	<b>9.3%</b>
<i>Lepus americanus</i> (Snowhoe Hare)	13.0	1.4	0.9	1.4	8		1.7	4.9	2.9		2	58.9	6	9.2
<i>Sylvilagus nuttallii</i> (Mountain Cottontail)				0.9										0.9
<b>Sciurids (Squirrels)</b>	<b>1.7%</b>	<b>11.4%</b>	<b>15.7%</b>	<b>27.6%</b>	<b>11.2%</b>	<b>24.0%</b>	<b>7.3%</b>	<b>3.0%</b>	<b>4.5%</b>		<b>7.0%</b>	<b>15.9%</b>	<b>9.0%</b>	<b>11.5%</b>
<i>Tamiasciurus hudsonicus</i> (Red Squirrel)	0.8	10	5.5	3.3	10.8	3	6.6		4		5	15.9	9	6.7
<i>Glaucomys spp.</i> (flying squirrels)	0.5	1.4		4.3	0.4		0.5	3	0.2		2			1.5
<i>Sciurus carolinensis</i> (Gray squirrel)			6			12								9
<i>Tamias striatus</i> (Eastern Chipmunk)	0.4		4.2	2.7		9	0.2							3.3
Unknown squirrel				17.3					0.3					8.8
<b>Birds</b>	<b>1.8%</b>	<b>15.7%</b>	<b>5.5%</b>	<b>19.5%</b>	<b>14.8%</b>	<b>22.0%</b>	<b>18.0%</b>	<b>8.8%</b>	<b>12.0%</b>	<b>10.0%</b>	<b>5.0%</b>	<b>17.8%</b>	<b>9.0%</b>	<b>12.3%</b>
<i>Bonasa umbellus</i> (Ruffed Grouse)	1.6	4.3	0.2		12.2							4.7		4.6
Other Birds	0.2	11.4	5.3		2.6				12			13.1		7.4
<b>Mustelids</b>	<b>2.9%</b>	<b>4.3%</b>		<b>0.8%</b>	<b>0.9%</b>	<b>3.0%</b>		<b>2.2%</b>	<b>0.1%</b>				<b>7.5%</b>	<b>2.7%</b>
<i>Martes americana</i> (American Marten)	0.7	1.4			0.8	3		2.2						1.62
<i>Mustela erminea</i> (Short-tailed Weasel)	2.1	2.9		0.8	0.1									1.5
<i>Mustela nivalis</i> (Least Weasel)	0.2													
<b>Other</b>	<b>3.1%</b>	<b>31.4%</b>		<b>27.1%</b>	<b>4.1%</b>	<b>84.0%</b>	<b>9.2%</b>	<b>9.4%</b>	<b>26.1%</b>		<b>9.0%</b>		<b>29.5%</b>	<b>23.3%</b>
<i>Neotoma cinerea</i> (Bushy-tailed woodrat)				2.5										2.5
<i>Cervidae spp.</i> (Cervid carrion)		30		2	2.4		0.7	1.2	4.7				7	6.9
Insects	3.1	1.4		22.4	0.7	81	8.3	8	21.4		9		15.5	17.8
Fish				0.2	0.3		0.2	0.2					7	1.6
Amphibians					0.7									0.7
Reptiles						3								3
<b>Plants</b>	<b>9.5%</b>			<b>13.3%</b>	<b>2.4%</b>	<b>90.0%</b>	<b>11.5%</b>	<b>7.6%</b>	<b>39.7%</b>	<b>17.0%</b>	<b>12.0%</b>	<b>21.4%</b>	<b>14.0%</b>	<b>21.7%</b>
Soft Mast	9.5			8.5	2.4						12			8.1
Wood fibers, lichen, grass				4.8										4.8

<sup>1</sup>Thompson & Colgan (1990) Manitowadge, Ontario

<sup>2</sup>Carlson et al. (2014) Northern Wisconsin

<sup>3</sup>Hales et al. (2008) Upper Peninsula of Michigan

<sup>4</sup>Bull (2000) Northeastern Oregon

<sup>5</sup>Cumberland et al. (2001) New Brunswick

<sup>6</sup>Kujawa et al. (2014) Lower Peninsula of Michigan

<sup>7</sup>Soutiere (1979) North-central Maine

<sup>8</sup>Zielinski et al. (1983) North-east California

<sup>9</sup>Weckwerth and Hawley (1962) North-west Montana

<sup>10</sup>Lensink et al. (1955) Interior Alaska

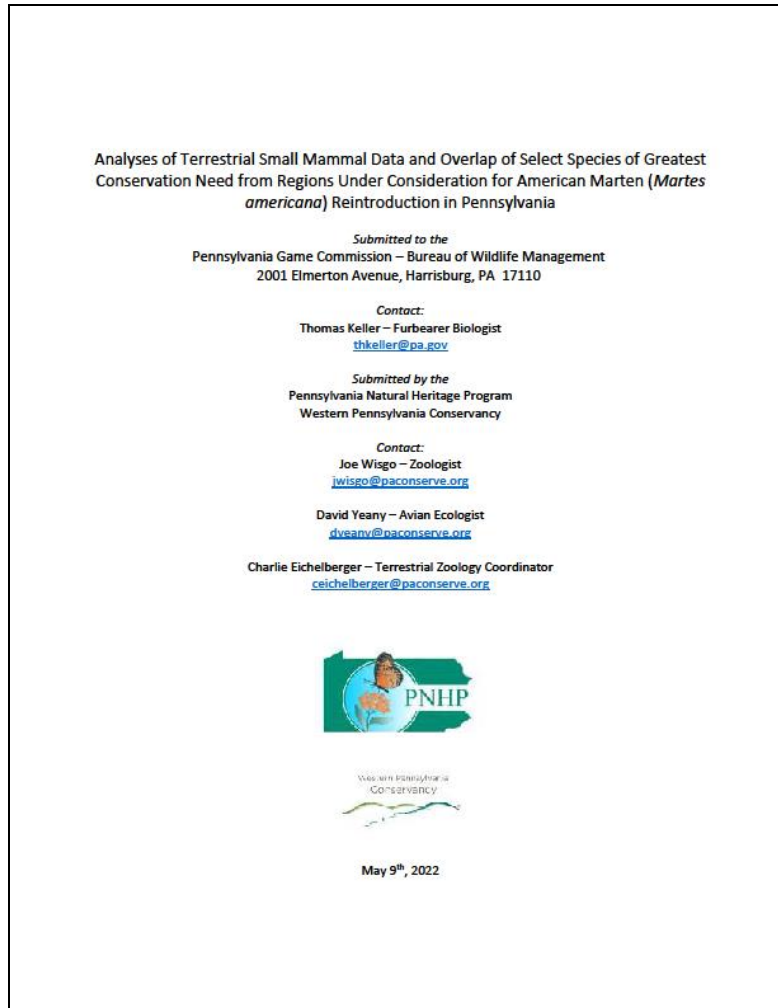
<sup>11</sup>Koehler and Hornocker (1977) Northern Idaho

<sup>12</sup>Raine (1981) South-eastern Manitoba

<sup>13</sup>Gordon (1986) North-central Colorado

## Appendix 2. Prey abundance, richness, and SGCN spatial consideration analysis from Western PA Conservancy.

(Double Click on Title Page to View WPC Report exported to PDF)





## Appendix 3. American marten habitat model Python Notebook and associated coding.

(Double Click on Title Page to View Python Notebook exported to PDF)

6/16/22, 2:39 PM AmMarten\_HSI\_FinalAnalysis

### American Marten Habitat Suitability

**Goal**

To identify if Pennsylvania has any suitable areas for American marten.

**Description**

Suitable habitat areas will be determined using multiple natural resource rasters. Each raster will be given Habitat Suitability Indices (HSI) based off Tom Keller and other expert opinions. A sum of the rasters will provide areas of high suitability on the landscape. Using suitable areas, site visits will be conducted for field verification. If it is determined that suitability areas exist, reintroduction of the species could be discussed as an option.


**Project Lead**

**Emily Kerstetter**

Geospatial Specialist, Northcentral Region,  
Pennsylvania Game Commission

Contact me with any questions at:  
emkerstett@pa.gov; Cell: (570) 507-0091;  
Desk: (570) 398-4744 ext 30330

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file:///C:/Users/emkerstett/DataTransfer/Excel Data/AmMarten\_HSI\_FinalAnalysis.html 1/21

## Appendix 4. Lion poll public opinion results and related questions.

		Gender						Age - Recode - Broad Categories						Do you consider yourself a hunter?					
		Man		Woman		Total		18-34		35-64		65 and older		Yes		No		Total	
		Count	%	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%
Have you ever heard of the American marten?	Yes	134	26.4%	96	17.8%	230	22.0%	52	17.8%	106	21.1%	72	28.6%	51	41.1%	176	19.3%	227	21.9%
	No	338	66.5%	389	72.2%	727	69.4%	221	75.7%	357	71.0%	149	59.1%	64	51.6%	659	72.1%	723	69.7%
	Don't know / Not sure	36	7.1%	54	10.0%	90	8.6%	19	6.5%	40	8.0%	31	12.3%	9	7.3%	79	8.6%	88	8.5%
	Total	508	100.0%	539	100.0%	1047	100.0%	292	100.0%	503	100.0%	252	100.0%	124	100.0%	914	100.0%	1038	100.0%
If it is possible, would you support or oppose efforts to bring the American marten back to Pennsylvania?	Oppose	34	7.4%	35	7.5%	69	7.5%	19	6.9%	34	7.7%	16	7.7%	10	8.5%	59	7.4%	69	7.5%
	Support	423	92.6%	434	92.5%	857	92.5%	257	93.1%	407	92.3%	193	92.3%	108	91.5%	741	92.6%	849	92.5%

The below information occurred following the first question regardless of answer. It occurs directly before question 2.

**Marten\_Description.** Please read the following information about the American marten carefully. The American marten is a small mammal that weighs about 1 to 3 pounds and measures 20 to 26 inches from its nose to the tip of its tail. Once native to Pennsylvania, it has disappeared from the state due to losing forest habitat in the late 1800s and early 1900s. There are still active populations in New York and other parts of the United States and Canada. It eats small animals, including squirrels, rodents, and birds, in addition to insects, fruits and nuts. Marten typically live in mature forested areas away from human development. This is a photo of an American marten.



Photo credit: Robert Sanders

**Marten Establish.** The Pennsylvania Game Commission is looking at whether it might be possible to reintroduce the American marten in Pennsylvania.