The Evolution of Land and Fire Management at Seney National Wildlife Refuge: From Game to Ecosystem Management

Dawn S. Marsh
Applied Sciences Program Intern
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1. Introduction

The idea of conserving natural resources in the United States became a topic of interest starting in the late 1800's as people became infatuated with the sublime nature of "wilderness," while at the same time exploiting under "Manifest Destiny." Ever since the implementation of the varying concepts of Gifford Pinchot, John Muir, and Theodore Roosevelt, land management methods have continued to evolve. Aldo Leopold's Game Management presented a, "creative use of the same tools which have heretofore destroyed it – axe, plow, cow, fire and gun," (Leopold, 1933). The ideals Leopold presented eventually became the basis of governmental regulations such as the *National Environmental Policy Act* of 1969 and the *Endangered Species Act* of 1973. Present-day land managers often use the continuum of philosophical approaches of Pinchot, Muir, Roosevelt, and Leopold while also incorporating more contemporary scientific findings into their decisions.

Many ecosystem types of the world are considered fire-dependent (Nowacki and Abrams, 2008). Fire, as a natural process, produces a mosaic of burned and unburned areas across a landscape and affects other important ecological processes, such as nutrient cycling, not to mention patterns in vegetation important to many wildlife species. When the fire regime of an environment is altered, from one that produced low to mixed severity surface burns to one that experiences less fire, for instance, the environmental conditions shift to favor fire sensitive, shade tolerant plant species. Eventually, in fire-dependent forest ecosystems the establishment of larger individuals of fire-sensitive plant species can create a closed canopy and promote a fire free ecosystem. Thus, fire suppression can act as a positive feedback cycle (Nowacki and Abrams, 2008). In the northern Lake States, many fire regime alterations have occurred as a result of anthropogenic activities. This can result in complex ecosystems becoming homogenized (Frelich, 2002).

The incorporation of fire in land management in the northern Lake States was initially met with great resistance. Although fire was an element that was used effectively by Native Americans to manage forests (Cleland, 1992) and blueberry (*Vaccinium*) crops (Anderton, 1999), to European settlers it was an element that had to be extinguished; it posed a threat to their timber and communities. Over time, however, fire became a tool that was used effectively to promote game species such as white-tailed deer (*Odocoileus virgianus*), Sharp-tailed Grouse (*Tympanuchus phasianellus*) and Greater Prairie Chickens (*T. cupido*), as well as broader communities and ecosystems.

Seney National Wildlife Refuge (Seney NWR or Refuge), located in the eastern Upper Peninsula of Michigan, provides an ideal landscape to examine changes in fire management philosophy and to compare spatial patterns of modern fires to fires that occurred before European settlement (pre-1860). Seney NWR has both benchmark areas (large, ecologically intact areas with few changes in the natural range of variation of processes, like fire return interval, and associated patterns) and areas that have been more intensively managed and currently do not emulate historic conditions well. Exploitive logging operations in the late 1800s

and early 1900s altered many of the terrestrial ecosystems by reducing the dominance of late successional mixed-pine (Corace et al., 2009). Later, ditching and wetland drainage promoted what ended up to be failed agricultural attempts on the landscape. Alterations continued to occur after Seney NWR was established in 1935, as a series of dikes and pools were established, with assistance from the Civilian Conservation Corps, to promote waterfowl habitat. These attempts ceased only when money ran out, saving nearly 40,000 acres from intensive management and alteration (the 25,150-acre Seney Wilderness Area and its Strangmoor Bog National Natural Landmark included). Currently, Seney NWR is restoring portions of the landscape to pre-European settlement conditions based on published patterns and processes (Drobyshev et al., 2008*a,b*; Seney NWR, 2013). In regards to fire, prescribed fires are conducted on a yearly basis; however, it is unknown whether or not these "controlled fires" reflect natural wildfire patterns, or if certain habitats are being targeted more frequently than one would expect from random.

Previously published work has focused on reconstructing the fire history of Seney NWR for three time intervals: pre-European settlement (pre 1707-1859), post-European settlement (1860-1935), and post-Refuge establishment (post-1935). Wedge sampling from red pine (*Pinus resinosa*), eastern white pine (*P. strobus*), and jack pine (*P. banksiana*) in Wilderness and non-Wilderness areas, as well as along outwash channels and sand ridges, occurred and the patterns of fire deduced through dendrochronology (Figure 1, Figure 2). Results showed moderate fire activity during pre-European settlement, increased fire activity post-European settlement, and diverging patterns in Wilderness and non-Wilderness areas post-Refuge establishment (Drobyshev et al., 2008*b,* Figure 3).

This report will examine the management values behind fire management at Seney NWR and how prescribed fires conducted since 1935 compare to pre-European settlement (pre-1860) wildfires, as described by Drobyshev et al. (2008*a*,*b*). This work addresses the following research questions:

1. How have wildlife values and other management values changed within the context of fire management at Seney NWR?

2. Do spatial patterns in prescribed fire at Seney NWR, since its establishment in 1935, mirror those of naturally caused wildfire occurring from 1707-1859 in average fire size, return interval, and proportion of cover type burned?

2. Background

2.1 Study Site

Seney NWR encompasses 95,238 acres and is operated by the United States Fish and Wildlife Service (USFWS) as part of the National Wildlife Refuge System (NWRS). The landscape exhibits a mosaic of upland and wetland habitats and current management divides the landscape into four management units, with the westernmost unit comprising 25,150 acres of

designated Federal Wilderness Area (Seney NWR, 2013). The Seney Wilderness Area contains the 9,600 acre Strangmoor Bog National Natural Landmark, one of the southernmost string bogs in North America. Seney NWR is a part of the Seney Sand Lake Plain complex ecoregion and soils are primarily sand, peat, and muck (Albert 1995). Coniferous forests and wetlands (including peatlands) predominate (Seney NWR, 2013).

2.2. Pre-Refuge Establishment Impacts on the Landscape

Research has shown that Native American use of the pre-European landscape was minimal, so it is likely that any impact caused on the environment by Native Americans and other humans at that time was insignificant (Silbernagel et al., 1997). The first anthropogenic alterations to the landscape started with the logging of the mixed-pine forests in the late 1800s and early 1900s (Graham, 1941, Maybee, 1960, Anderson, 1982). However, due to inaccessibility, the Seney Wilderness Area was minimally impacted by logging (Drobyshev et al. 2008*a,b*, Rist, 2008). In 1908, the Western Land Surety Company purchased the Seney marshes from Cleveland Cliffs Mining Company to drain the area and advertise the land as being suitable for agricultural purposes (Losey, 2003). The draining of the wetlands significantly altered the hydrology of the area by diverting the water flow of the Driggs River. One of the agricultural attempts occurred on 8,000 acres near the north-end of present-day Refuge boundaries. The Bullock Ranch, as it was called, was operational from 1916-1933 and was one of the largest farms in the Upper Midwest. The ranch raised cattle, sheep, and hogs, and grew rye, oats, and wheat (Losey et al., 2007). Overall, much, but not all, of the Seney landscape was marred by logging, repeated fires outside the natural range of variation, hydrological alterations, and land clearing (Seney NWR, 2013).

2.3 Refuge Impacts on the Landscape

Due to failed agricultural attempts on the landscape and tax delinquency, the property was acquired by the State of Michigan and then transferred to the federal government for development as a site for waterfowl production. On December 10, 1935, Seney Migratory Waterfowl Refuge was established by presidential proclamation to promote waterfowl resting and nesting areas (Losey 2003). To accomplish this, the Refuge constructed a network of 27 anthropogenic pools. These pools currently range in size from approximately 100 to 1000 acres (Seney HMP, 2013). However, the Refuge is not located within a major migratory flyway and the underlying soils are nutrient poor, so the pools were not as productive as the Refuge had hoped and current management is de-emphasizing these anthropogenic impoundments (Seney NWR, 2013).

3. Methods

3.1 Management and Wildlife Values in Relation to Fire over Time

In order to examine the changes in land and fire management values over time, Seney NWR's Annual Narratives were accessed. Overall, 67 years of Annual Narratives were analyzed. The Annual Narratives began as a quarterly report and eventually became an Annual Report that was submitted to the USFWS Regional Office (Minneapolis, MN) yearly until 2009. The narratives provide an overview of the Refuge's accomplishments for the year, including the

amount of time and money invested, as well as the reasoning behind these projects. Each narrative covered the same points of interest, but may have been formatted differently or used different codes. Each quarterly narrative, or annual narrative, from 1937 to 2009, with the exception of 1999-2001 and 2007-2008 (missing), was examined for any mention of the word "fire". If "fire" was mentioned, the pages were then photocopied and considered data. Once the narratives were examined and copies made, the text regarding management decisions, wildfires, or the current fire status was typed into a word document to further compress the 67 (1937-2009, not including the aforementioned missing narratives) years of data into one document. A spreadsheet was then created to categorize the management ideals regarding the use of fire, at the time, into five categories that were assumed to best represent the management history at the Refuge: 1) fuel load reduction, 2) game, 3) non-game/ecosystems, 4) other, and 5) unknown. The categorization of each prescribed fire was determined by the actions carried out by Refuge staff and/or the included thoughts of the current Refuge Manager. Once the Refuge began using prescribed fires as a management tool, the species and habitats were often, but not always, noted in the literature and were included in the spreadsheet for further analysis. The main species or taxa targeted for prescribed fires were categorized as follows: humans, Canada Goose (*Branta canadensis*), Sharp-tailed Grouse/Greater Prairie Chicken, Yellow Rail (*Coturnicops noveboracensis*), native vegetation, and multiple taxa. Humans were included as the focus of fuel load reduction. Management values over time were plotted in comparison to major events in landscape management history such as: Aldo Leopold's 1933 Game Management, the establishment of the Wildlife Society in 1937, Society for Conservation Biology in 1985, Society of Ecological Restoration in 1987, the *National Environmental Policy Act* of 1969, the *Endangered Species Act* of 1973, the 1997 *Refuge Improvement Act*, and the first publication of the journal *Ecosystems* in 1998. All findings were explored graphically, not statistically; no tests were made to support or not support hypotheses.

3.2 Examining Spatial Patterns between Pre and Post-European Settlement Fires on the Landscape

To examine fire spatial patterns, such as how the average size and range of sizes, of prescribed fires since 1935 compared to wildfires prior to 1860 and the proportion of area in different cover types within prescribed fire polygons, previously published data (Drobyshev et al. 2008*a,b*) were compared with the recent work of Rouser (2013) and other data. The published data described the pre-European settlement (pre-1860) fire patterns on the landscape while the recent work characterized the patterns in the prescribed fire management since 1935. Polygons describing the location and size of prescribed fires (Rouser and Corace, 2013 unpub. data) were used in Esri's ArcMap software with a Seney NWR land cover (cover type) layer. This data layer is based on 2004 aerial imagery (grain size ~1 ha) classified to the National Vegetation Classification Standard (NVCS; USGS 2012). The fire polygon shapefile data were reprojected to the universal transverse Mercator (UTM) coordinate systems to decrease spatial errors. Data pertaining to post-Refuge establishment wildfires were deleted. The "Intersect" tool, found under "Analysis", was used to combine the fire polygon data with Seney NWR land cover. The resulting attribute table did not separate the cover type acreage burned by each prescribed fire, so the "calculate geometry" feature was used on the "Acreage"

column. The resulting information was then sorted by year to distinguish between fires that had the same "Fire Name." This report uses nine cover types, as defined in the Habitat Management Plan (Seney NWR, 2013, Table 1). The "Open Water (Pools)" land cover type is not included in this analysis. The cover types were also categorized as "upland" or "wetland" for a broader analysis. In addition to examining the spatial patterns prescribed fires, the size of the fires, in terms of acreage, were also compared to data ranging from 1707 to 1859 (Table 2), as produced and presented by Drobyshev et al. (2008*a,b*) through dendrochronology. The fire return interval of the Refuge's prescribed fires was determined by examining overlapping polygons, in the fire history shapefile, and calculating the time between fires.

4. Results

4.1 Fire History of the Refuge Post-Establishment

Seney NWR was established during a time when suppression was the answer for dealing with fires on the landscape. In 1936, the Refuge spent 4,150 man days suppressing marsh and wildfires. The following year, Seney NWR was equipped with proper firefighting equipment and erected a fire tower (Seney NWR, 1937). C.S. Johnson, the Refuge Manager at the time, stated, "periodic rains have reduced the fire hazard to a minimum and for the first time in its history the refuge has enjoyed relief from constant vigilance and fire suppression activities," (Seney NWR, 1938). When there were no fire outbreaks on the Refuge, the manager wrote, "we are as of last year again obligated to the weather man for the favorable fire season. No man days were lost in firefighting and the work program has benefitted accordingly" (Seney NWR, 1939). Fire was a nuisance to Refuge staff and after a mild winter many were nervous about the impending threat of a long firefighting season. In an attempt to reduce the fire hazard, the Civilian Conservation Corps cleared and burned material that could have later been used as fuel in a devastating wildfire (Seney NWR, 1941). When the threat of fire was high, but weather conditions prevented fires, the Refuge Manager stated, "no doubt our official prayers were heard and kindly received" (Seney NWR, 1943).

In the mid 1940's, the upland game birds on the Refuge were being negatively impacted by the natural secondary succession of vegetation occurring on the cut over/burned over landscape (Seney NWR, 1944). Sharp-tailed Grouse, or sharptails, require an open landscape and will only stay in the area as long as it remains unforested. Therefore, disturbances such as fire or logging are required to set back encroaching vegetation. The Sharp-tailed Grouse at Seney NWR were commonly found on the former Bullock Ranch property (Losey et al., 2007). The Refuge recognized the need for action to be taken, but was met with conflicting opinions regarding the value of fire in improving habitat for another species, the Greater Prairie Chicken (Seney National Wildlife Refuge, 1944). The USFWS was facing resistance locally against the idea of using fire to improve habitat for game species. Johnson stated: "Perhaps it does take a lot of courage to make an about face on any conservation principle which has been fed to the public to the saturation point. But it now happens that the viewpoint on this matter is changing" (Seney NWR, 1945).

In 1946, the Refuge was still focused on improving Greater Prairie Chicken habitat, as their populations were declining. The staff was interested in conducting a prescribed fire and using

the proposed success of the burn as propaganda to gain support from the general public. Johnson stated: "From several sources comes the official nod toward promoting better upland game bird habitat by this method. Acknowledgement is made that it may take some time to educate the public toward this state of mind. This office is of a different opinion and endorses the idea of trying it first and showing the beneficial results as they accrue rather than following the usual barrage of printed propaganda which does not penetrate very deeply if absorbed at all" (Seney NWR, 1946). In late 1946, the Refuge's proposal to burn Greater Prairie Chicken habitat was approved; however, the 11,200 acre prescribed fire was unsuccessful due to heavy rains (Seney NWR, 1947).

After attempting to burn in 1947, the Refuge tried again in 1948 with mixed results. Some of the locations were not fit for burning and the objectives were unattainable. The idea of using prescribed fire to improve game habitat had, "emerged from the status of questionable character to one similar of a country cousin who might have money" (Seney NWR, 1948). The following year, C.S. Johnson relocated and was replaced by C. J. Henry. The USFWS continued to try and change opinion on using prescribed fire and had, for the most part, convinced the state game men; however, the majority of the Conservation Department continued to frown upon using fire as a management tool and the Refuge was forced to idly wait for a hapless hunter to start a fire in optimum Greater Prairie Chicken habitat (Seney NWR, 1950). Eventually, the State agreed to work with the USFWS and cooperatively burn upland game habitat in the fall of 1952. The prescribed fire was one of the Refuge's first large scale prescribed fires and gave the Refuge much needed courage and confidence. The Refuge attempted to determine the effect of marsh burning on willows (*Salix* spp.), tag alders (*Alnus serrulata*), and other brush, but the project failed due to poor plot placement (Seney NWR, 1952). After Seney NWR was able to successfully use fire as a land management tool repeatedly, the manager wrote, "Even the local people are remarking that we need more burning to improve wildlife habitat – this is the ultimate" (Seney NWR, 1954).

The Refuge continued to use prescribed fires to promote game and their habitat well into the later part of the 20th century. In 1970, the Refuge Manager wrote that the Refuge was using prescribed fires to, "kill encroaching woody vegetation, clean the area of thick litter, and stimulate the growth of green succulents for geese feed" (Seney NWR, 1970). Wildfires on the Refuge were infrequent and were often started by recreationalists. In 1976 a wildfire, started by lightning, consumed over 73,000 acres before it was eventually extinguished. The Refuge noted that the fire would be highly beneficial to wildlife habitats (Seney NWR, 1976). Anderson (1982) reported that the total diversity of wildlife on the Refuge increased following the fire, but the diversity decreased in the burned areas. Seney staff in the 1980's began the transition from managing specifically for game species to managing ecosystems and non-game species. The Refuge was compartmentalized for management purposes. One of the compartments was manipulated to improve habitat diversity for Sharp-tailed Grouse, Sandhill Cranes (*Grus canadensis*), and American Woodcock (*Scolopax minor*) with the primary objective of restoring the landscape to 1935 habitat conditions (Seney NWR, 1983).

Beginning in the 1990's, the Refuge Manager began including the following statement in the annual narratives regarding fire management practices on the Refuge: "Seney has a wide

diversity of wildlife utilizing habitats that include: string bogs, large sedge wetland complexes; red, white and jack pine; lowland conifers; a variety of hardwoods and managed impoundments. With the exception of the impoundments, all habitats evolved with periodic wildfires determining species dominance and diversity. Prescribed fire is being used to regenerate a variety of hardwoods and pine in some habits while in other areas fire and cutting is used to maintain and create large openings" (Seney NWR, 1990). The refuge's prescribed fire program had become one of the Refuge's highlights (Seney NWR, 1992). After decades of persistence, the use of prescribed fires had become an integral part of the Refuge's land management practices, but, in 1996, the Refuge underwent budget cuts and the prescribed fire program's budget was reduced from $125,000 to $20,000 and the number of prescribed fires conducted declined significantly (Seney NWR, 1996).

Although the prescribed fire program had been reduced, the Refuge continued to focus on restoring regional-level biodiversity levels by restoring and managing forest and wetland composition and structure (Seney NWR, 2002). In 2003, the primary fire management focus was to rebuild the prescribed fire program after it had been absent for nearly five years (Seney NWR, 2003). The following year, Seney NWR conducted 14 prescribed fires (Seney NWR, 2004). The largest prescribed fire, since 1947, was conducted in 2009 and burned approximately 4,500 acres (Seney NWR, 2009).

4.2 Quantitative Analysis of Management Values

The Refuge focused solely on reducing fuel loads until the mid-1940's when increasing Canada Goose, Sharp-tailed Grouse, and Greater Prairie Chicken populations became the primary focus. The use of fire as a tool for game management lasted until the 1980's and eventually evolved to encompass non-game species and ecosystems. The use of fire to solely reduce fuel loads dominated fire management from the establishment of Seney NWR in 1935 until approximately 1948. Prescribed fires were used to improve game populations from approximately 1948 through 1986, and the use of prescribed fires for non-game, ecosystems, and the prevention of large-scale wildfires began in 1987, and is still in use today. Therefore, strictly fuel load reduction lasted 13 years, game management lasted 38 years, and non-game/ecosystem management has occurred for over 26 years. Over the years, a variety of species were the objective of these prescribed fires, including American Woodcock, Greater Prairie Chicken, Sharp-Tailed Grouse, Sandhill Crane, Canada Goose, Yellow Rail, American black bear (*Ursus americanus*), and white-tailed deer.

Of the 106 prescribed fires examined in the Annual Narratives, 40 did not provide enough information to determine the reasoning behind them; these accounted for 38% of all prescribed fires. Multiple taxa were targeted for 30% of the fires, followed by Canada Goose (11%). Prescribed fires set to improve native vegetation accounted for 8 fires (8%) and 6 fires were set to benefit humans by reducing fuel loads (7%) Sharp-tailed Grouse and Greater Prairie Chicken habitats were the focus of 5 fires (5%). Prescribed fires were also executed in Yellow Rail habitat on three occasions (3%) to examine the impacts of fire on Yellow Rail habitat use. In regards to the reasoning behind each of these 106 fires, burning to improve non-game habitat and ecosystems in general accounted for 42%, game management was the focus behind 14% of the fires, fuel load reduction to reduce the potential for future catastrophic wildfires was the

focus of 4 fires (4%), and three fires were conducted to examine the impact of fire equipment on the landscape (3%). Influential publications, policies, and societies were plotted on a time line that shows the number of prescribed fires that were conducted each year, as well as the reasoning behind each fire to examine any relationships that may exist (Figure 4). A visual examination suggests Refuge fire management may lag behind developments within the broader field of natural resource management or ecology, more specifically.

4.3 Examining Spatial Patterns between Pre and Post-European Settlement Fires on the Landscape

When prescribed fires were compared to pre-European settlement (1707-1859) wildfires (Table 2), it was found that the size of wildfires in the non-Wilderness and Wilderness areas were larger in size, ranging from 5 to 23,786 acres, while the Refuge's prescribed fires ranged from 1 to 4,490 acres. The average prescribed fire size varied over time (Figure 5). The fire return interval (FRI) of pre-European settlement fires ranged from 3 to 72 years (Table 2), while the FRI of prescribed fires, in areas where overlapping fires occurred, was much shorter and ranged from 1 to 41 years, with an average of 8.35 years between burns. The shortest fire-return intervals were located around the Refuge's pools.

The acreage of each prescribed fire, broken down by cover type as defined by the Habitat Management Plan (2013), was graphed over time (Figure 6). The figure shows that the scrub-shrub and open wetland cover types make up the greatest proportion of acreage burned for a given prescribed fire. The average proportion of cover type burned in a prescribed fire was calculated (Table 3). When the cover types were further simplified and defined as being an upland or wetland cover type, the graph (Figure 7) shows that wetland cover types are commonly the majority of acreage burned in each prescribed fire.

5. Discussion

5.1 Management and Wildlife Values

The Annual Narratives showed a gradual change in management and wildlife values over time, but when the reasoning behind each prescribed fire is graphed alongside influential acts of Congress, publications, and the establishment of professional societies it is difficult to discern the catalyst of these changes in land management practices. Aldo Leopold's Game Management most likely influenced the Refuge to examine the use of fire as a land management tool; however, the first prescribed fire didn't occur until 1948, 15 years after Game Management was published. The *National Environmental Policy Act* of 1969, may have had an influence on the shift from strictly using prescribed fire for game species to using fire to promote multiple taxa and ecosystems, as the Refuge was already using prescribed fire to improve ecosystems when the Society for Conservation Biology and the Society of Ecological Restoration were established. Overall, there is no distinct correlation between the graphed events and the reasoning behind each prescribed fire. Similarly, the number and size of the prescribed fires in a given year varied over time which is most likely due to changes in Refuge's budget.

5.2 Spatial Patterns between Pre and Post-European Settlement Fires on the Landscape

Seney NWR's prescribed fires are significantly smaller than the fires that occurred on the landscape prior to European settlement, especially when compared to the wildfires that occurred in the Non-Wilderness area. This can be attributed to the fact that prescribed fires are controlled and the acreage is predetermined based on the goals and objectives of the fire. The fire-return interval of wildfires occurring before 1860 in the non-Wilderness area was approximately three times higher than the present-day fire return interval of prescribed fires. The Refuge's prescribed fires often occur in the same locations, generally around the pools, and are burned regularly.

The proportion of each cover type burned in a given prescribed fire remained fairly consistent over the course of the years. The scrub-shrub and open wetland cover types generally accounted for the largest proportion of acreage burned in each prescribed fire. This may be attributed to the fact that these cover types often support populations of species that were promoted by the Refuge, including Sandhill Crane, Canada Goose, Yellow Rail, etc. When the average proportion of each cover type burned in a prescribed fire is examined, it is clear that certain cover types are being targeted more frequently, specifically the scrub-shrub and old fields and upland openland cover types, while other types are underrepresented (Table 3). The more frequently targeted cover types are often associated with targeted game species and vegetation surrounding the anthropogenic pools. Therefore, the average proportion of each cover type burned do not emulate natural occurring wildfires.

Conclusion

Seney National Wildlife Refuge's landscape and land-use history has made it an ideal location to examine the differences between wildfires occurring pre-European settlement and prescribed fires conducted by the Refuge, as well as the changes in land management and wildlife values, in regards to fire, over time. The Refuge gradually shifted from using fire strictly to reduce fuel loads, in hopes of reducing the chances of a catastrophic wildfire, to using fire as a tool to promote game populations and ecosystems. Seney NWR's prescribed fires have a shorter fire return interval and are smaller than naturally occurring wildfires, largely due to the controlled nature of a prescribed fire. In terms of cover type, the Refuge's prescribed fires mirror pre-European settlement wildfires, in regards to the average proportion of upland and wetland cover type burned; however the average proportion of each cover type burned in a given prescribed fire is imbalanced with an emphasis on cover types that support game species or surround the anthropogenic pools. Therefore, the spatial patterns found in the prescribed fires conducted by Seney NWR do not mirror pre-European settlement wildfires in terms of fire return interval, size, and proportion of cover type burned.

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by stakeholders across the Lake States region and subscribes to the set of core values outlined by the Joint Fire Science Program.

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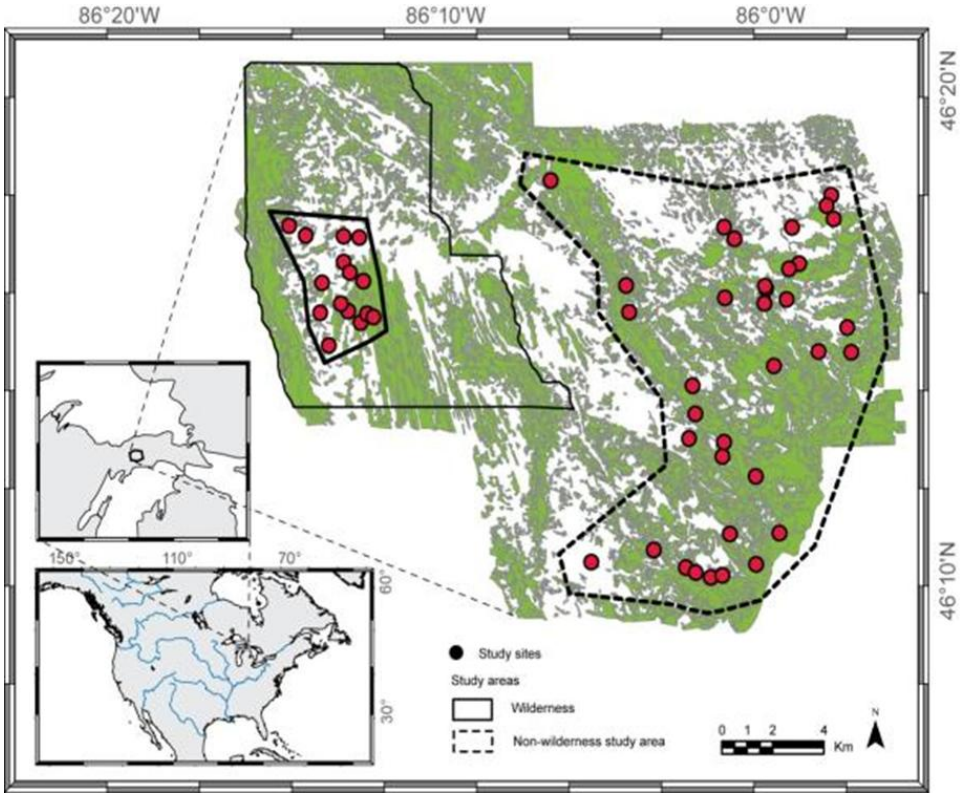

Figure 1. Location of fire sites used for dendrochronologically reconstructing the 300+ year fire history at Seney National Wildlife Refuge (Drobysev et al., 2008*a,b*).

Figure 2. Example of fire scarred wedge from a red pine used for dendrochronology (Drobyshev et al., 2008*a,b*)

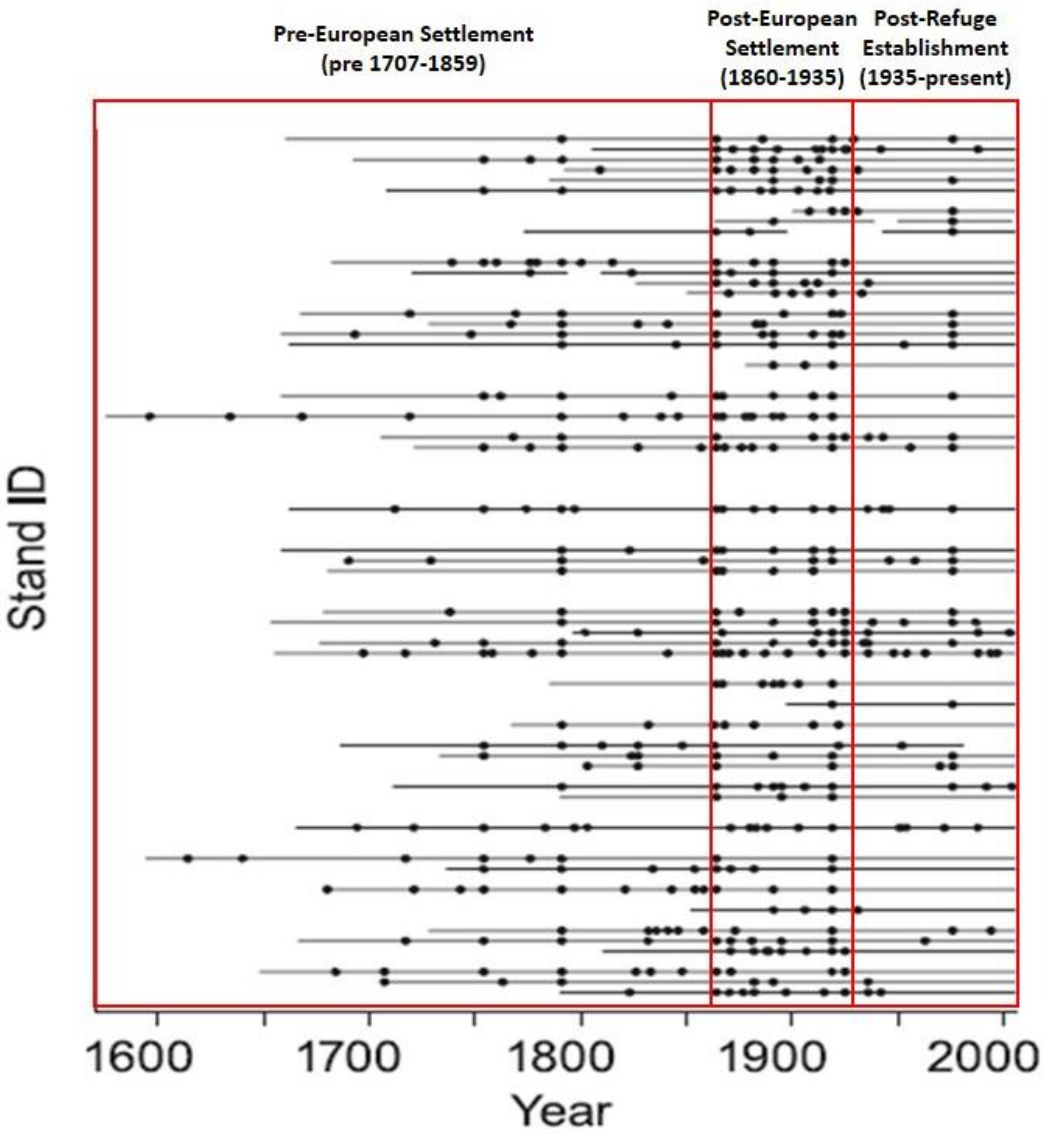

Figure 3. Fire return intervals for 53 specific fire sites at Seney National Wildlife Refuge (Drobyshev et al., 2008*a,b*). Each line represents a spatially unique fire site and each dot a fire recorded. Multiple fires are recorded on many of the sites because most fires were not stand-replacing.

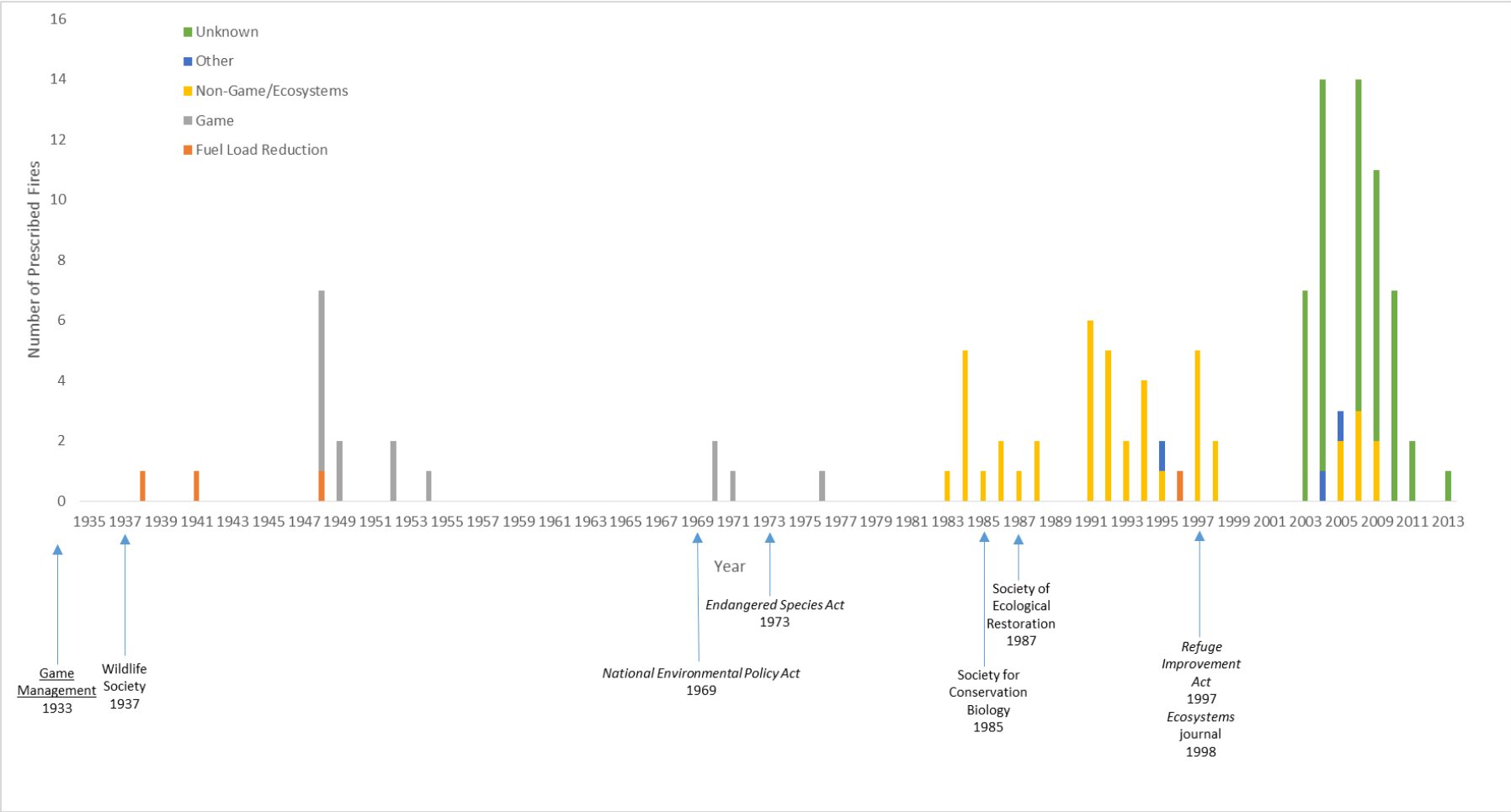

Figure 4. Number of prescribed fires in a given year over time since Refuge establishment (1935). Also plotted are events of note.

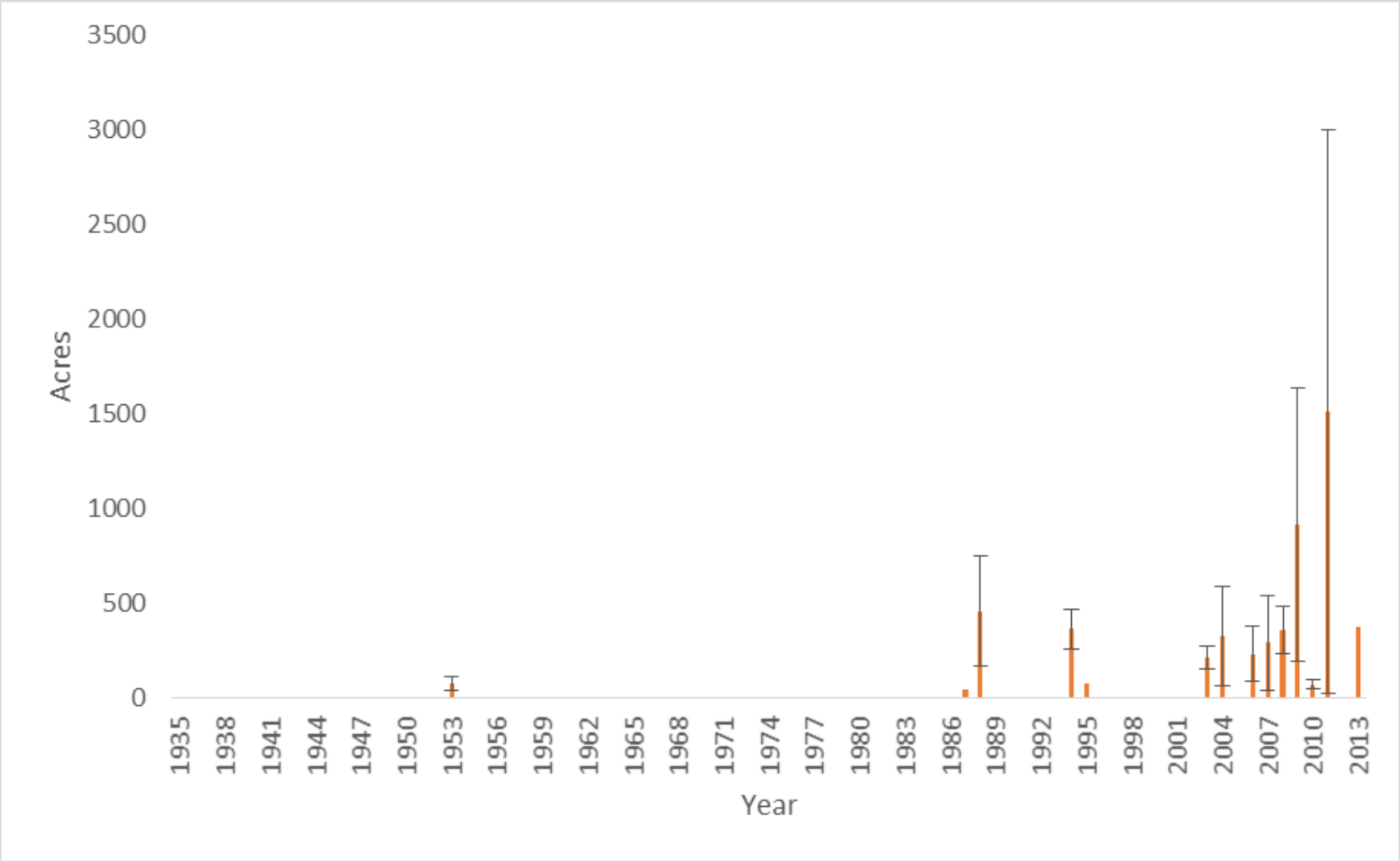

Figure 5. Average (±1SD) prescribed fire size over time.

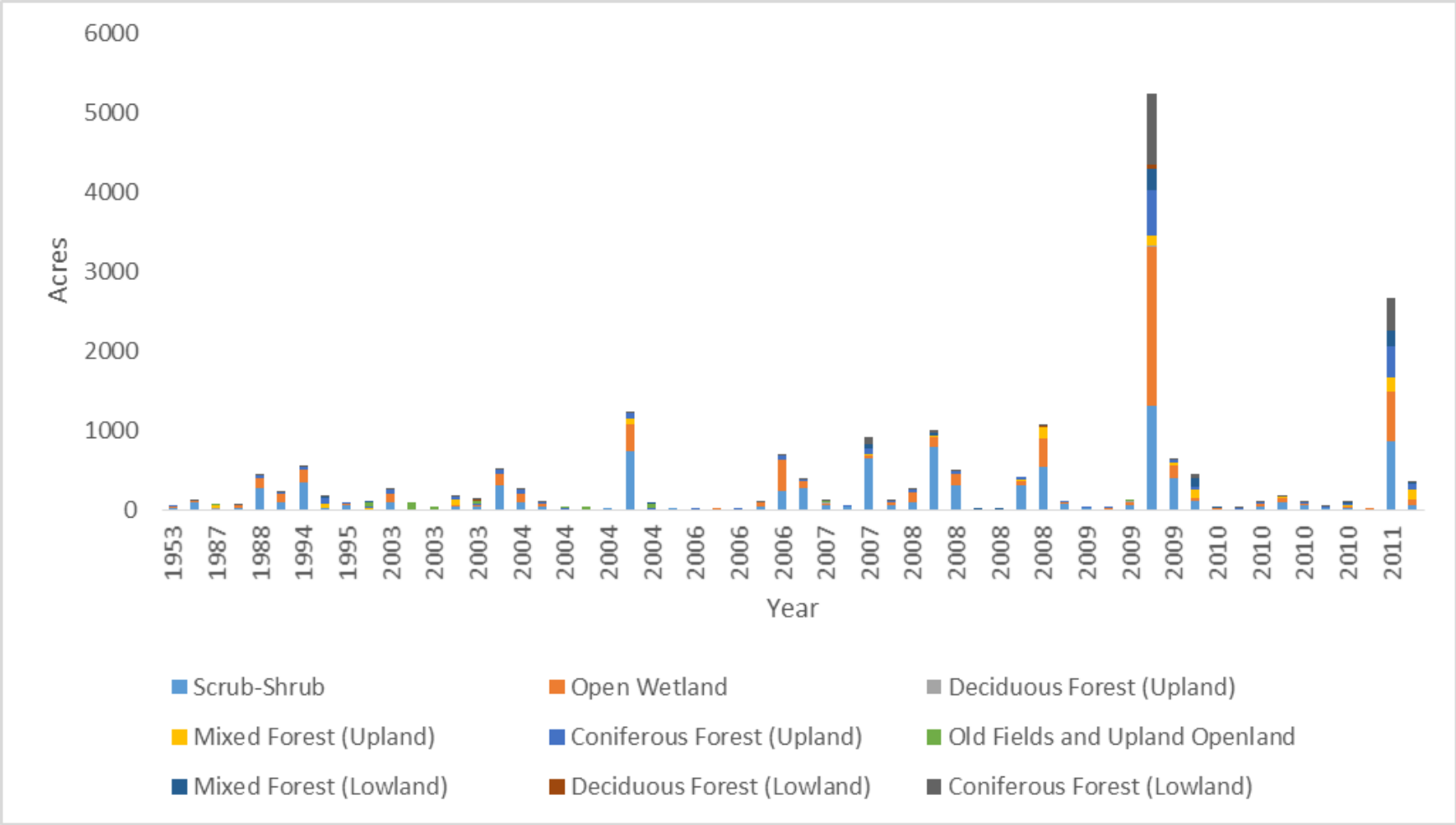

Figure 6. Prescribed fire acreage burned by cover type.

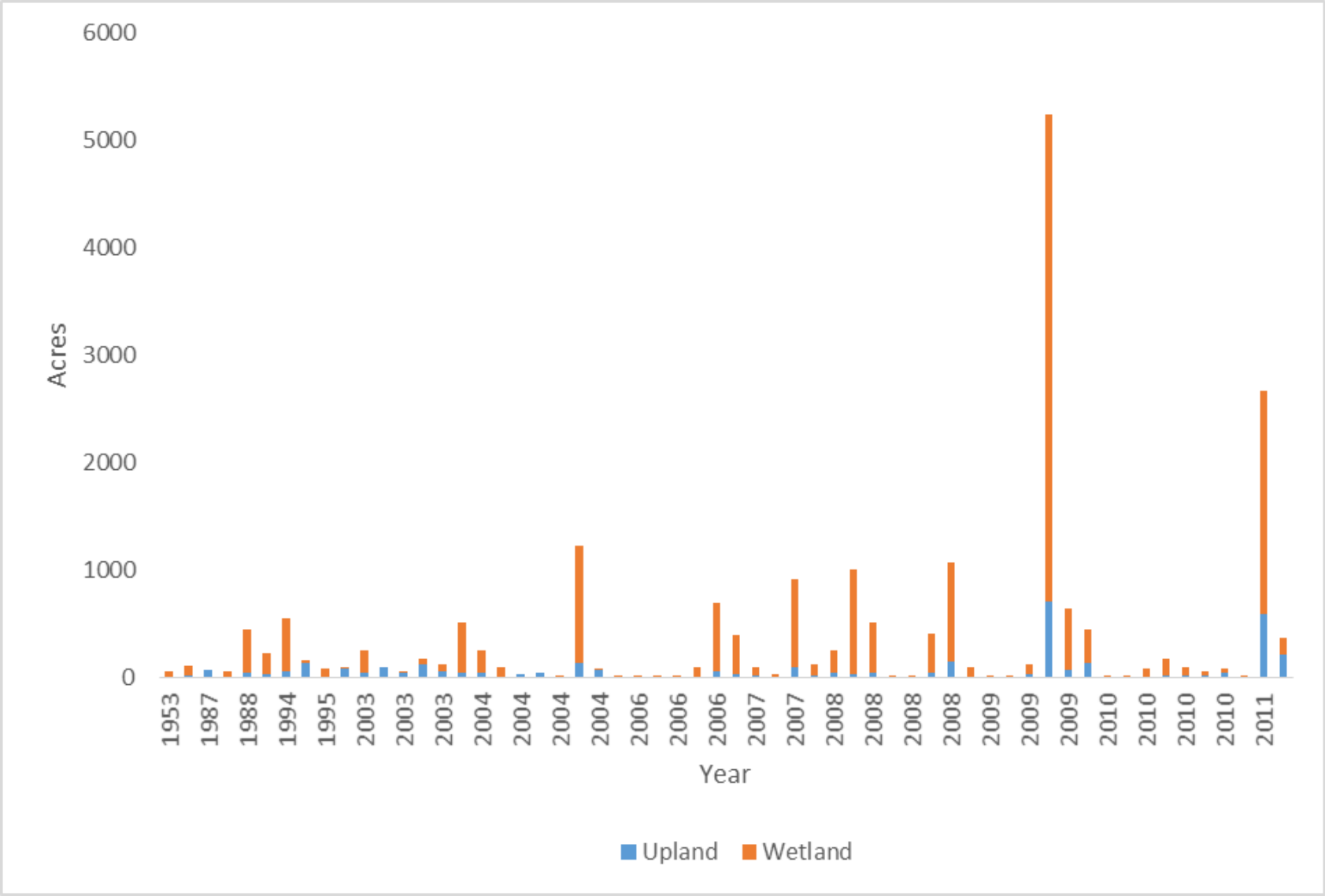

Figure 7. Prescribed fire acreage burned in upland and wetland cover type.

Table 1. Cover codes used in analysis, as defined by the Habitat Management Plan (Seney NWR, 2013).

Land Cover Code	**Acres**	**Percentage**
Scrub-Shrub	28,953.66	30.4
Open Wetland	16,923.34	17.8
Mixed Forest (Upland)	11,395.55	12.0
Coniferous Forest (Upland)	8,856.78	9.3
Mixed Forest (Lowland)	8,220.55	8.6
Coniferous Forest (Lowland)	7,824.62	8.2
Open Water (Pools)	4,796.93	5.0
Deciduous Forest (Upland)	4,371.81	4.6
Deciduous Forest (Lowland)	2,515.36	2.6
Old Fields and Upland Openland	1,302.12	1.4
Total	**95,160.72**	

Table 2. Wildfire data as produced by Drobyshev et al. (2008*a,b*) showing average fire return interval (years) and mean fire size (acres) with range in parenthesis.

Time Period (1707-1859)	
Fire Return Interval (Years)	
Wilderness	32.7 (5-72)
Non-wilderness	24.3 (3-70)
Fire Size (Acres)	
Wilderness	172.97 (4.94-3830.13)
Non-wilderness	1228.11 (14.83-23786.36)

Table 3. Average proportion of cover type burned per prescribed fire from 1935-2013.

Land Cover Code	Acres	Percentage	Average Percentage Burned per Prescribed Fire
Scrub-Shrub	28,953.66	32.0%	43.20%
Open Wetland	16,923.34	18.7%	22.1%
Coniferous Forest (Upland)	8,856.78	9.8%	10.9%
Old Fields and Upland Openland	1,302.12	1.4%	9.6%
Deciduous Forest (Upland)	4,371.81	4.8%	8.0%
Mixed Forest (Upland)	11,395.55	12.6%	7.5%
Coniferous Forest (Lowland)	7,824.62	8.7%	2.9%
Mixed Forest (Lowland)	8,220.55	9.1%	2.8%
Deciduous Forest (Lowland)	2,515.36	2.8%	0.2%
Total	**90,363.79**		