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FIELD NOTE

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Historical and recent fire ecology on national wildlife refuges: a case study on Aransas National Wildlife Refuge

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Abstract

Background The southeastern United States consists of diverse ecosystems, many of which are fire-dependent. Fires were common during pre-European times, and many were anthropogenic in origin. Understanding how prescribed burning practices in use today compare to historic fire regimes can provide perspective and context on the role of fire in critical ecosystems. On the Aransas National Wildlife Refuge (ANWR), prescribed burning is conducted to prevent live oak (*Quercus fusiformis*) encroachment and preserve the openness of the herbaceous wetlands and grasslands for endangered whooping cranes (*Grus americana*) and Aplomado falcons (*Falco femoralis*). This field note builds a digital fire atlas of recent prescribed burning on the refuge and compares it to the historical fire ecology of ANWR.

Results Findings indicate that the refuge is maintaining fire-dependent ecosystems with an extensive burn program that includes a fire return interval between 2 and 10 years on a majority of the refuge, with some locations experiencing much longer intervals. These fire return intervals are much shorter than the historic burn regime according to LANDFIRE.

Conclusions Following the fire return intervals projected by LANDFIRE, which project longer intervals than the prescribed fire program, would likely be detrimental to endangered species management by allowing increased woody plant encroachment and loss of open habitat important to whooping cranes and Aplomado falcons. Since prescribed fire is part of the management objectives on many national wildlife refuges in the United States, quantifying recent and historical fire ecology can provide useful insights into future management efforts, particularly in cases where endangered species are of special concern and management efforts may be counter to historical disturbance regimes.

Keywords Burn regimes, Fire-dependent ecosystem, Mean fire return interval, Landsat, Normalized burn ratio, Prescribed fire

Resumen

Antecedentes El sudeste de los EEUU consiste en diversos ecosistemas, muchos de ellos fuego-dependientes. Los fuegos fueron comunes durante la era pre-europea, y muchos de ellos de origen antrópico. El entender cómo las quemas prescriptas en uso en estos tiempos se comparan con regímenes de fuegos históricos puede proveer de una perspectiva y el contexto sobre el rol del fuego en ecosistemas críticos. En el Refugio Nacional de Fauna Silvestre

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de Aransas (ANWR), las quemas prescriptas son conducidas para prevenir la invasión de árboles de roble fusiforme (Quercus fusiformis) y preservar la apertura de claros en humedales herbáceos y pastizales para especies en peligro como la grulla chillona (Grus americana) y el halcón plomizo (Falco femoralis). Esta nota de campo construye un atlas digital de incendios de quemas prescriptas recientes en ese refugio y la compara con la historia de la ecología del fuego del refugio ANWR.

Resultados Los resultados indican que el refugio mantiene los ecosistemas dependientes del fuego mediante un extensivo programa de quemas prescriptas que incluye un retorno de intervalo del fuego de entre 2 y 10 años en la mayoría del refugio, con algunos lugares experimentando muchos mayores intervalos. Estos intervalos de retorno del fuego son muchos más cortos que el régimen de fuegos históricos de acuerdo con el programa LANDFIRE.

Conclusiones Siguiendo los intervalos de retorno del fuego proyectados por LANDFIRE, que proyectan intervalos más largos que el programa de quemas prescriptas, estos serían detrimentales para el manejo de las especies en peligro, ya que se incrementarían las especies leñosas y por lo tanto se reducirían los espacios abiertos que son importantes para la grulla chillona y el halcón plomizo. Dado que las quemas prescriptas son parte de los objetivos de manejo de muchos refugios de fauna de los EEUU, la cuantificación de la ecología del fuego reciente e histórica puede proveer de perspectivas útiles en esfuerzos de manejo futuros, particularmente en casos en los que especies en peligro requieren de una consideración especial y los esfuerzos de manejo pueden ir en contra de los regímenes de disturbios históricos.

Introduction

Fire plays an important role in natural ecosystems, but fire suppression has become a dominant paradigm of land management over the past century (Keane et al. 2002; Dombeck et al. 2004; Bowman et al. 2011). In the United States, fire suppression throughout most of the 20th-century has generally resulted in altered fire regimes and accumulation of fuel, leading to more extreme and severe wildland fires in many locations (Ryan et al. 2013; Stambaugh et al. 2014a). Following World War II, an explicit focus on fire suppression was enhanced as an increase in manpower and surplus military equipment allowed additional resources to be used to fight wildland fires. Since then, some federal agencies in the United States have continued to take a reactive approach to fighting fires rather than proactively addressing fire-dependent ecosystems by maintaining them through prescribed burns (Dombeck et al. 2004; Dale 2006). As fire suppression has proved unsuccessful in preventing large wildland fires, prescribed burning has re-emerged as a viable tool to reduce fuel loads. However, individual land management agencies must decide if prescribed burning is an appropriate tool for ecosystem management and whether programs should aim to match the historic fire regime or whether a new fire regime should be established based on agency objectives.

The United States Fish and Wildlife Service (USFWS) has maintained prescribed fire programs on national wildlife refuges and provides a compelling case from which to assess fire management practices and examine the effects of prescribed fire regimes on the landscape. The USFWS was given a clear mandate for developing and implementing management objectives under the National Wildlife Refuge System Improvement Act of 1997 (Dolin 2003), with each refuge encouraged to manage for historical conditions, including the use of fire when applicable (Schroeder et al. 2004; Meretsky et al. 2006). Since then, the USFWS has expanded its policies to focus on using prescribed burns to improve wildlife habitat, reduce fuel loads, and maintain fire-dependent ecosystems on lands they manage. However, the USFWS faces a challenging conundrum when reintroducing fire to the landscape: whether to attempt to return the landscape to historic conditions or to manage the landscape for current objectives resulting in different vegetation communities compared to the past. A topic of debate surrounding ecosystem restoration includes whether historic conditions should be used as a reference point for restoration or if an ecosystem service-based approach is warranted given that ecosystems are dynamic and specific management goals that often guide restoration efforts may not follow historic disturbance regimes (Hiers et al. 2012; Dey and Schweitzer 2014). Understanding how a prescribed burn program will alter the existing vegetation community is important and necessary for implementing management objectives for wildlife refuges because the complex interactions between fire and other land management activities may have unintended consequences for wildlife populations (Fontaine and Kennedy 2012). These considerations are particularly relevant for wildlife refuges that contain critical habitat for endangered species where the need to protect these species often guides and prioritizes management activities. Aransas National Wildlife Refuge (ANWR) is a USFWS refuge that has been using prescribed burns since the 1980s to manage critical habitat for endangered species, specifically whooping cranes (*Grus americana*) and Aplomado falcons (*Falco femoralis*).

Understanding the implications of potential state changes of vegetation communities resulting from prescribed burn programs is key for quantifying program impacts on land management activities and allocating future funding to maintain these programs. This field note presents a record of fire ecology of ANWR to better understand how the current prescribed burn regime compares to the historical regime. The objectives of this study were to (1) map the long term (1985–2013) prescribed burn regime using a remote sensing-based workflow and the spatial distribution and magnitude of recent burning and compare it to both historical records and LANDFIRE, and (2) analyze the impacts of the prescribed burn regime on the vegetation community using high spatial resolution land cover data to provide guidance on balancing the habitat requirements for federally threatened and endangered species that utilize the refuge.

Methods

Study site

ANWR is a remnant of a coastal prairie fire-dependent ecosystem located along the southeastern coast of Texas, USA (Fig. 1). The refuge is composed of five administrative units (Aransas, Tatton, Matagorda Island, Myrtle Foester-Whitmire, and Lamar) totaling about 47,000 ha and buffered by over 5,200 ha of bay area waters under protection by the USFWS (for a more detailed description, see Aransas National Wildlife Refuge Comprehensive Conservation Plan and Environmental Assessment [USFWS 2010]). The refuge consists of fire-adapted vegetation communities that have historically burned due to natural ignitions and intentional burning by Native Americans and early settlers (Lynch 1941; Hanselka 1980; Sparks et al. 2012; Stambaugh et al. 2014b). On the main portion of the refuge (Aransas/Tatton Unit, called Aransas from here forward), the most prevalent vegetation type is the Texas coastal bend live oak (*Quercus fusiformis*) – redbay (*Persea borbonia*) forest, followed by the Texas coastal bend interdune swale grassland, which is adapted to both fire and periodic flooding (USFWS 2010).

Shortly after the refuge was established in the late 1930s, cattlemen noted that burns were needed to reduce and prevent brush buildup (Halloran 1943). Woody plant encroachment on coastal grasslands is a problem for conservation as both the endangered whooping cranes and Aplomado falcons prefer open habitat (Saintilan and Rogers 2015). Live oak has spread throughout ANWR, covering much of the refuge beyond the immediate coastal areas. In the 1980s, ANWR implemented a prescribed burning program to maintain woody vegetation at early successional stages and low canopy heights to foster visibility for the protected whooping cranes, aid them in predator detection, and promote foraging and roosting

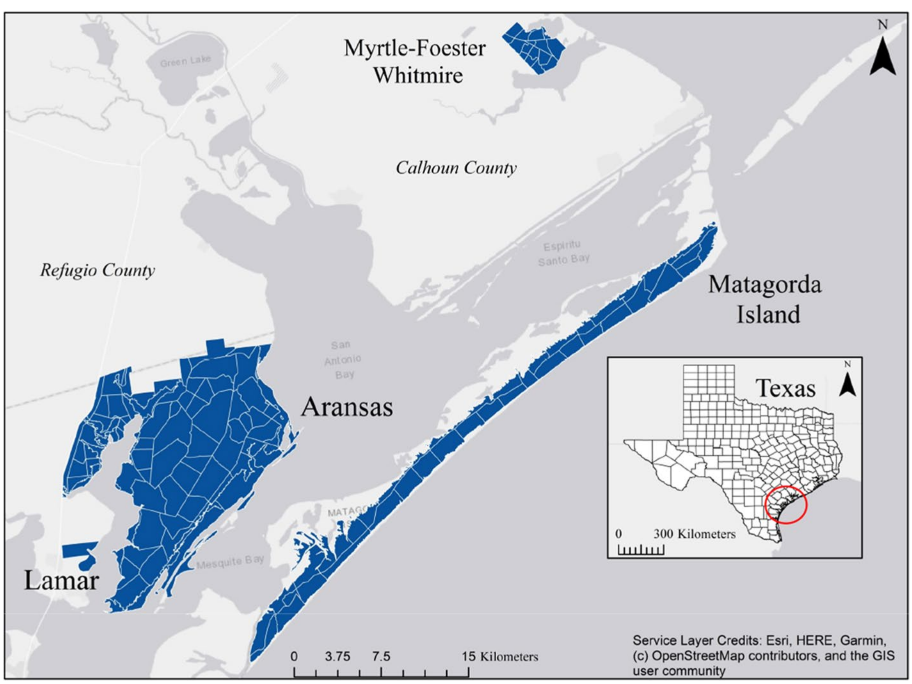

Fig. 1 Location of the Aransas National Wildlife Refuge, Texas, USA (Aransas/Tatton, Lamar, Matagorda Island, and Myrtle Foester-Whitmire units) along the Texas Gulf Coast. Administrative burn units delineated by the refuge are outlined in white

(Armbruster 1990; Lewis 1995; Chavez-Ramirez 1996; Chavez-Ramirez et al. 1996; Golden et al. 2022). Studies have shown that repeated summer burns decrease stem densities and result in more open thickets (Kelley 1980; Hays 1999), therefore, summer burns are conducted at ANWR to prevent woody encroachment (USFWS 2010) and winter burns are conducted to facilitate foraging opportunities for whooping cranes (Chavez-Ramirez 1996).

Data preparation and processing

Mapping the Recent Fire Regime with Landsat

We used satellite remote sensing to develop a digital atlas of all fires conducted between 1985 and 2013 as part of ANWR's prescribed burn program. Using Landsat imagery, we delineated burn perimeters and indexed fires based on their severity to give land managers a better understanding of the spatial and temporal extent of historical burns on the landscape (Henry and Yool 2002). When fire destroys the cell structure of plants, chlorophyll production decreases, which influences spectral reflectance in the mid-and near-infrared regions of the electromagnetic spectrum (Patterson and Yool 1998; Jensen 2007). The Normalized Burn Ratio (NBR) leverages these wavelength regions based on the theory that healthy vegetation reflects light strongly in the near-infrared (NIR) portion, and burned areas have reduced absorption of shortwave infrared (SWIR) radiation due to decreased water content (Rogan and Yool 2001; Key and Benson 2006). Normalizing reflectance values from the SWIR band with values from the NIR band enhances burned areas on an image, allowing for more accurate burn mapping. NBR is computed as:

$$NBR = \frac{Band4 - Band7}{Band4 + Band7}$$

Differencing NBR values from before and directly after a fire allows burned areas to be differentiated from non-burned areas. The differenced normalized burn ratio (ΔNBR) is defined as:

$$\Delta NBR = NBR_{pre-fire} - NBR_{post-fire}$$

ΔNBR ranges from -2 to 2, with values near zero suggesting little change over time and thereby indicating areas that likely did not burn. Positive ΔNBR values from ~ 0.1 to ~ 1.35 are indicative of areas that have experienced a burn, whereas values greater than 1.35 are likely to be clouds (Key and Benson 2005).

We obtained a database from the USFWS of 481 prescribed burns performed at the refuge from 1985 thru 2013, including the ignition date, the mapping unit in which the burn was conducted (Fig. 1; units are specific to ANWR), and the estimated acreage of each burn. Although wildland fires may have occurred on the refuge complex, only one was documented in the database and was excluded from our analyses. Using the ignition dates, we obtained cloud-free, Landsat images before and after each burn from the US Geological Survey Earth Resources Observation and Science Center (http://glovis.usgs.gov). Imagery from both Landsat TM and Landsat ETM + were considered to increase the pool of available image dates, but use of ETM + images collected after 30 May 2003 was limited due to the scan line corrector failure. Due to the sub-tropical climate of south Texas, images captured more than three months after a fire are not likely to show evidence of a burn as vegetation regrows quickly (Lonard et al. 2004). Therefore, fires for which a cloud-free image could not be identified within three months after the ignition date were not mapped. Pre-fire images could be captured up to one year prior to the burn, as it is rare for ANWR to burn the same area twice in a single year.

NBR was computed for the pre- and post-fire images, and values were differenced to compute ΔNBR. Following the threshold guidelines noted above along with visual validation, ΔNBR pixel values ranging from 0.15 to 1.50 were classified as burned. Contiguous pixels classified as 'burned' were vectorized to create a spatial polygon representing the burn extent. The accuracy of the mapped burns was verified by refuge staff (W. Harrell, U.S. Fish and Wildlife Service, Albuquerque, New Mexico, USA, personal communication).

A total of 375 burns (~ 78% of the original 481 burns in the database) were mapped from 1985–2013 (Table 1). One hundred and six burns could not be mapped due to a lack of cloud free images, which is common in sub-tropical regions. We were able to account for 58 of the missing burns through an archive analysis and first-hand knowledge from refuge staff to estimate the administrative unit where those burns occurred, providing a mean fire return interval (MFRI; discussed below) that is slightly different than the map shown in Fig. 2. Our mapping rate of 78% is within the average capture rate dependent on usable imagery from LANDSAT for the southeastern United States (Picotte and Robertson 2011).

To quantify the spatial distribution and magnitude of prescribed burning on the refuge, we computed basic descriptive statistics using the mapped burn polygons. By overlaying the polygons, we computed the MFRI for each pixel as well as each administrative burn unit (see Fig. 1) for the 28-year study period. We then classified the study period into approximately five-year increments and categorized each pixel in the study area based on the number of time periods in which it was burned. We modeled the spatial and temporal changes in fire patterns over the

Table 1 Descriptive statistics of prescribed burns on Aransas National Wildlife Refuge (1985–2013) computed using the digital fire atlas

Years	No. of fires mapped	No. of fires not mapped	Min. mapped fire size (ha)	Max. mapped fire size (ha)	Mean of mapped fires (ha) (±sd)	Sum of mapped burned area (ha)
1985–1989	24	9	9.3	1,264.7	374.8 (±310)	8,995.0
1990–1994	50	19	8.2	863.2	156.3 (±135.5)	7,816.4
1995–1999	98	49	2.0	1,024.8	166.8 (±172.3)	16,344.0
2000–2004	60	11	5.5	398.4	157.3 (±110.6)	9,348.0
2005–2009	93	15	7.7	669.7	163.0 (±126.3)	15,162.0
2010–2013	50	3	5.1	1,356.2	218.2 (±246.8)	10,907.6
1985–2013	375	106	2.0	1,356.2	183.1 (± 181)	68,573.0

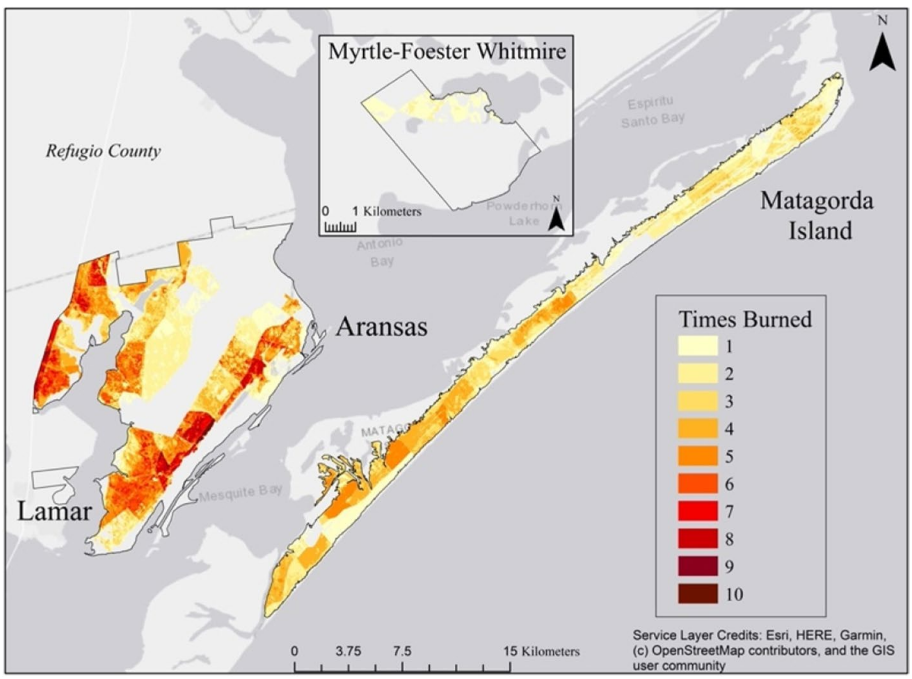

Fig. 2 Number of times each area was burned during the study period (1985—2013) on Aransas National Wildlife Refuge, Texas, USA

5-year increments using the StampR package in R (Robertson et al. 2007; Long and Robertson 2018) in order to highlight areas the refuge burns regularly.

Contextualizing the Historic Fire Regime with LANDFIRE

We used the Landscape Fire and Resource Management Tools Project (LANDFIRE) to build a historical fire ecology of ANWR to compare to the recent (1985–2013) fire regime. LANDFIRE was developed by the US Forest Service and the Department of the Interior to provide a nationally complete, comprehensive, and consistent set of products to support planning, fire, and natural resource management across the conterminous United States. There are more than 20 geospatial layers of vegetation, fuel, disturbance, and other variables to understand and contextualize wildland fire management.

We used the MFRI and Fire Regime Group (FRG) layers to develop an understanding of the historical fire regime on ANWR as these metrics align most closely to the variables we mapped for the current fire regime. The MFRI represents the time between fires based on the assumed historic fire regime, with 22 classes ranging from 0–5 years (continuous to frequently burned) up to > 1,000 years (USGS 2013). The FRG represents the historic fire regime for a given area by classifying areas based on fire return interval and burn severity: Group I is a ≤ 35-year return interval with low and mixed severity fire, Group II is a ≤ 35-year return interval with replacement severity level fire, Group III is a 35–200 year fire return interval with low and mixed severity fire, Group IV is a 35–200 year fire return interval with replacement severity, and Group V is a 200+year fire return interval at any level of severity. We computed the hectares of each MRFI and FRG group on the refuge and compared these findings to descriptions of the historic fire regime in the area from Stambaugh et al. (2014b), Frost (1998), and Guyette et al. (2012).

Vegetation community classification data

To assess how the recent prescribed burn regime relates to the existing vegetation communities on the refuge, we used the Terrestrial Ecological Systems classification system created by NatureServe and the Missouri Resource Assessment Partnership (MoRAP) (NatureServe 2009; Ludeke et al. 2010a, 2010b). The MoRAP data include a thematic map (10 m resolution) of detailed ecological systems generated using remote sensing, ground-reference data, soil types, riparian areas, and digital elevation models (Ludeke et al. 2010a). Vegetation types are based on the Terrestrial Ecological Systems Classification by NatureServe. The 32 vegetation classifications present on ANWR were aggregated into four general classes: grassland, forest/woodland, wetland/marsh, and shrubland. We aggregated these vegetation classifications as the prescribed fire program is focused on these structural components of vegetation for managing whooping crane habitat. Since the data are only available for a single time point (2004–2005), it is not possible to measure the impact of prescribed burning on the vegetation community directly. However, they can be used to understand the spatial relationship between the areas in which burning is performed and the existing vegetation communities at those sites on the refuge. We overlaid the MoRAP data with the digital atlas of prescribed burns for 2005 and calculated basic statistics to determine which vegetation communities have been burned most frequently.

Results

Digital atlas of prescribed fires

On average, the refuge conducted 13 prescribed burns per year with an average burn size of 183 ha (Table 1). About 35% of burns were less than 100 ha, about 30% were between 100 and 200 ha, and about 35% were greater than 200 ha. Large portions of the refuge were burned multiple times between 1985 and 2013 (Fig. 2), resulting in high mean fire return intervals (Fig. 3). Some areas were burned ten times or more over the 28-year study period, whereas areas in the center of the main Aransas unit and the coastal areas, which are tidal, were never burned. On Matagorda Island, most areas were burned between one and five times.

The mean fire return interval for administrative burn units ranged from 2 to >28 years (Fig. 3). While we were able to account for some of the missing burns, even with

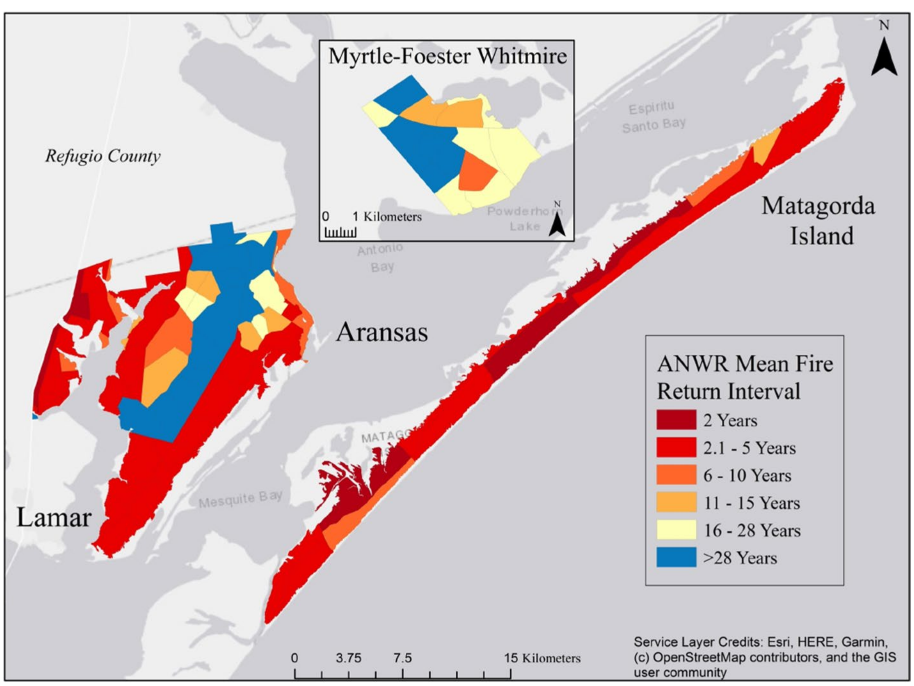

Fig. 3 Mean fire return interval per administrative prescribed burn unit between 1985–2013. Blue units indicate areas where no burns were detected from 1985–2013. Aransas National Wildlife Refuge, Texas, USA

these additional data, our estimate of the MFRI for each unit is conservative, as 48 burns remain missing. On Aransas, the mean fire return interval was 7.5 years, with a range of 1.3 to > 28 years. Sections of the main unit that were not burned during the 28-year study period likely have a much greater fire return interval. On Matagorda Island, the mean fire return interval was 4.8 years, with a range of 1.8 to 14 years (Fig. 3). Much of the Myrtle Foester-Whitmire Unit has been burned in recent years, however ANWR did not acquire this unit until 1993 and did not implement prescribed burning until 2004.

Results indicate that the refuge consistently burns many of the same locations, with the southern coast of Aransas, the northwestern portion Aransas (Tatton unit), and the majority of Matagorda Island receiving regular burn prescriptions (see Supplemental Information). MoRAP shows that the areas burned (in 2005) were mostly grassland and shrubland, which together account for more than 70% of the land area on the unit and more than 85% of the areas burned (Table 2). Established forest/woodland accounts for about 11% of the land area of ANWR, but only about 7% of the area burned. Wetlands, which account for 18% of the land area on ANWR, were less than 4% of the area burned. A chi-square test showed that the areas burned in each habitat type are significantly different than what would be expected if fires were randomly distributed ($p < 0.001$). These results provide support that the refuge is using prescribed fire to actively manage woody cover in grasslands and shrublands, which aligns with one of their goals of maintaining open areas for the benefit of whooping cranes and Aplomado falcons (CWS and USFWS 2007).

Historic fire regime

According to LANDFIRE, 60.9% of the refuge is in Fire Regime Group III (a historical mean fire return interval of 35–200 years with low and mixed severity fire) (Fig. 4). More than a third of the refuge (37.5%) is classified as Group II (an MFRI of 35 years or less with replacement severity fire), and less than 1% is classified as Group I (≤35-year MFRI with low and mixed severity fire). The LANDFIRE results indicate that the refuge historically burned with an interval between 35 and 200 years with low and mixed severity fire. Most of the refuge (59.84%) had a LANDFIRE mean fire return interval of 81–90 years, while 23.65% had a fire return interval of 26–30 years. Just over 10% of the refuge had a fire return interval of 0–5 years (Fig. 5). The LANDFIRE results suggest that the recent burn regime on ANWR differs greatly from the historical regime and burning is much more frequent than it was in the past.

Discussion

The choice by land management agencies to mimic a historic fire regime or develop a contemporary fire management plan can have substantial implications for wildlife management. ANWR is faced with the challenge of developing a management strategy to restore historic conditions on the refuge or implementing a much different management strategy for endangered and threatened species with each strategy resulting in different outcomes (Schroeder et al. 2004). We found that the prescribed mean fire return interval for many areas of ANWR aligns with accounts of historic fire frequencies published in the literature but is much shorter than the interval reported in the LANDFIRE database.

We triangulated the findings through historical accounts, which suggest that burning was common throughout Texas (Lynch 1941; Box et al. 1967; Sparks et al. 2012), particularly the Southern Coastal Plain (Hanselka 1980) and that low intensity fires contributed to the presence of open grasslands and savanna-like ecosystems in the southeastern United States (Boyd 1999; Fowler and Konopik 2007). The general consensus is that southeastern Texas, including the Gulf Coast, had a very short MFRI between 2 and 12 years (Frost 1998; Guyette et al. 2012; Stambaugh et al 2014b), which is supported by historical accounts of the use of anthropogenically-ignited fire on this landscape. These historical accounts align more closely with the findings from our digital fire atlas than the LANDFIRE data. Low severity fire was likely more common at ANWR than high severity stand-replacing fires, based on both landscape structure and vegetative fuel, supporting the view that coastal Texas had a short fire return interval indicative of a fire-dependent ecosystem. While the geographic scales

Table 2 Vegetation types present on Aransas National Wildlife Refuge based on MoRAP vegetation data and the percentage of each type burned by prescribed fires in 2005

Vegetation type	Total hectares on ANWR	Percent of ANWR land area	Total hectares burned	Percent burned of total hectares on ANWR	Percent of total hectares burned
Grassland	13,031.8	40.0	1,259.9	9.7	44.9
Shrubland	10,062.5	31.0	1,230.4	12.2	43.9
Wetland/Marsh	5,854.5	18.0	108.0	1.8	3.9
Forest/Woodland	3,513.5	11.0	204.6	5.8	7.3

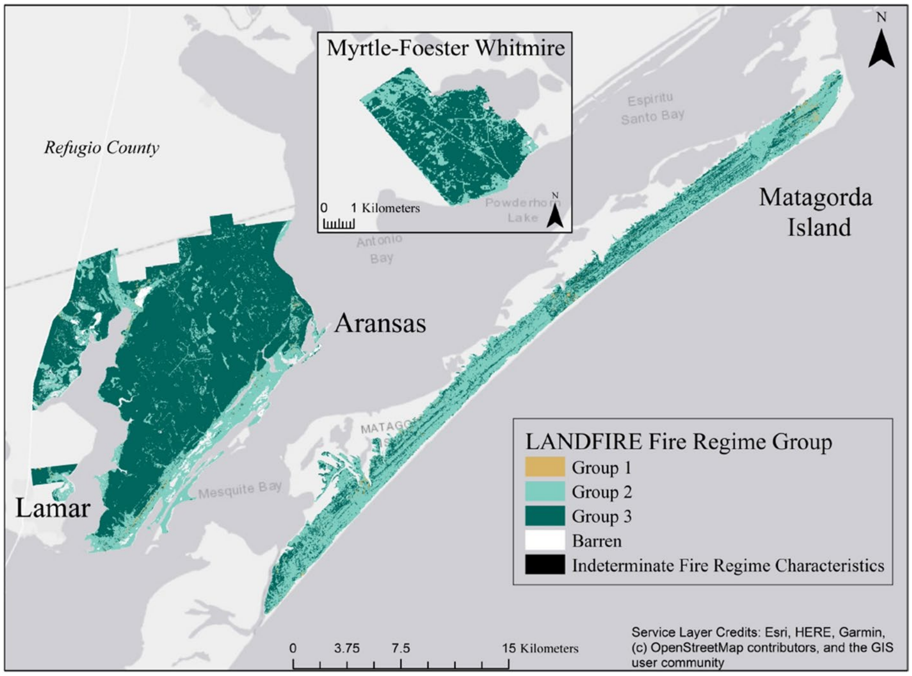

Fig. 4 LANDFIRE Fire Regime Group (FRG) classification on Aransas National Wildlife Refuge, Texas, USA

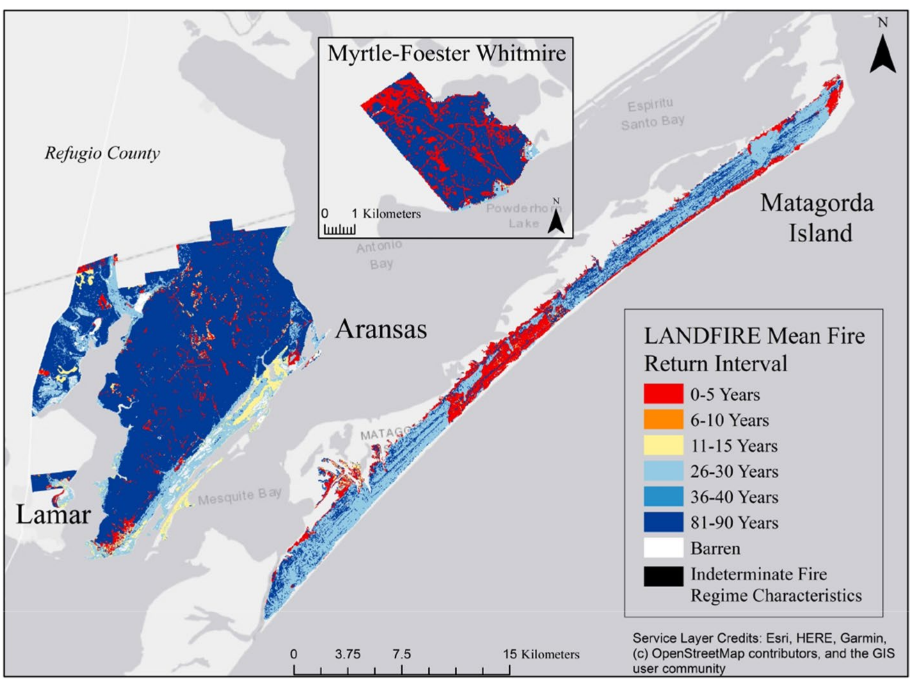

Fig. 5 LANDFIRE Mean Fire Return Interval (MRFI) classification on Aransas National Wildlife Refuge, Texas, USA

represented in the literature vary (e.g., some studies are regional, others continental, etc.), these archives provide a useful context to interpret the historic burn regime of the Texas Gulf Coast region. Additionally, the use of data including fire scars and evidence of charcoal from sediment cores, combined with historical records and digital mapping, can provide an in-depth look at the historical fire regime.

The landscape structure and climate on ANWR support the need for a frequent fire return interval to slow the spread of woody species and maintain critical habitat for wildlife. ANWR is susceptible to woody invasion due to rainfall and overall productivity levels because it is located in a subtropical climate (Ratajczak et al. 2012; Archer et al. 2017) and therefore, the refuge must consider encroaching woody species as a potential problem that prescribed fire can help ameliorate. The encroachment of woody species can increase or decrease the existing fuel load and create a feedback loop that results in a changed fire regime, and combined with other natural disturbances on the refuge, including herbivory and significant weather events such as hurricanes, can permanently change the vegetation communities present, potentially altering critical habitat for endangered species (Brooks et al. 2004; Zouhar et al. 2008).

Both the whooping crane and Aplomado falcon have specific habitat requirements, and fire is used to maintain the appropriate extent of oak communities, open grassland, and wetlands for these federally listed endangered species. The MoRAP data showed that the refuge is primarily burning grassland and woody shrubland vegetation types. Whooping cranes that utilize ANWR tend to not be observed in areas of dense live oak woodland and shrubland (Golden et al. 2022). Continuous prescribed burns help set back vegetation to early successional stages and lower overall plant height as whooping cranes prefer unobstructed views that allow for predator detection (Armbruster 1990), roosting, and foraging (Lewis 1995) as do Aplomado falcons for hunting prey and breeding, particularly on Matagorda Island (Perez et al. 1996; Macías-Duarte et al. 2004; Hunt et al. 2013). Using LANDFIRE intervals to guide prescribed burning may be detrimental to whooping crane management, and it is likely that the open habitat critical to both whooping cranes and Aplomado falcons use of the refuge would be lost to woody plant encroachment. Prescribed fire can meet refuge objectives such as maintaining the grasslands and prairie habitat as well as the coastal savanna habitat that benefits not only endangered species but also other focal species such loggerhead shrikes (*Lanius ludovicianus*), seaside sparrows (*Ammospiza maritima*), and painted buntings (*Passerina ciris*) (USFWS 2010).

Lastly, this field note provides evidence of the ability to use satellite mapping to provide a comprehensive and accurate account of prescribed burn history. Even with the very fast regeneration time for vegetation in a sub-tropical climate, Landsat captured nearly 80% of burns that occurred on the refuge. The long-term archive of Landsat imagery, going back to the mid-1980s, permits retroactive assessments to provide a precise record of fire management on the refuge. For other agencies looking to use fire as a management option, digitally mapping fire perimeters immediately after they are conducted, either via GPS or imagery, can help improve the accuracy of reporting metrics such as area and exact location burned. The recent availability of very high spatial (<5 m) and temporal (daily repeat) imagery from companies like Planet and Maxar has the potential to make burn scar mapping even more reliable and precise. The technology on Planet cubesats is evolving rapidly and is responsive to a budding user community (Frazier and Hemingway 2021), and the recent addition of short-wave infrared channels on the Planet cubesats will aid in high precision fire mapping. Another option for land managers is to use drones to collect their own imagery post-fire to compute metrics of burn area, fire severity, and other metrics. While these technologies cannot be employed retroactively to map past fires, they can be integrated into monitoring programs in the future.

Conclusions

The ecosystems of ANWR have developed in response to both the presence of fire (i.e., fire-adapted species present on the refuge) and the lack of fire on the landscape (i.e., the spread of invasive woody plants). The risk of following the historic burn regime according to LANDFIRE would likely create a scenario of increased woody plant encroachment in ANWR. The need to manage habitat for critically endangered and threatened species here should take precedence over returning the landscape to presumed historic conditions. The loss of biodiversity is a larger ecological concern if species were to go extinct; therefore, maintenance of biodiversity should be a more important primary objective than historic restoration of the fire interval, particularly on refuges with critical habitat designations.

Abbreviations

ANWR	Aransas National Wildlife Refuge
FRG	Fire regime group
MoRAP	Missouri Resource Assessment Partnership
MFRI	Mean fire return interval
NBR	Normalized burn ratio
ΔNBR	Differenced normalized burn ratio
NIR	Near infrared
SWIR	Shortwave infrared
USFWS	United States Fish and Wildlife Service

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s42408-024-00273-z.

Supplementary material 1.

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Authors' contributions
The research design was conceptualized by all authors. Methodology and formal analysis were completed by Katherine Golden and Benjamin Hemingway. Original draft preparation was completed by Katherine Golden, Amy Frazier, Benjamin Hemingway, Craig Davis, and Sam Fuhlendorf. All authors contributed to revising the manuscript.

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Availability of data and materials
The data used in the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors have no conflict of interest or competing interests to declare.

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