High frequency monitoring of fire regimes and ecological resilience across the Okefenokee National Wildlife Refuge

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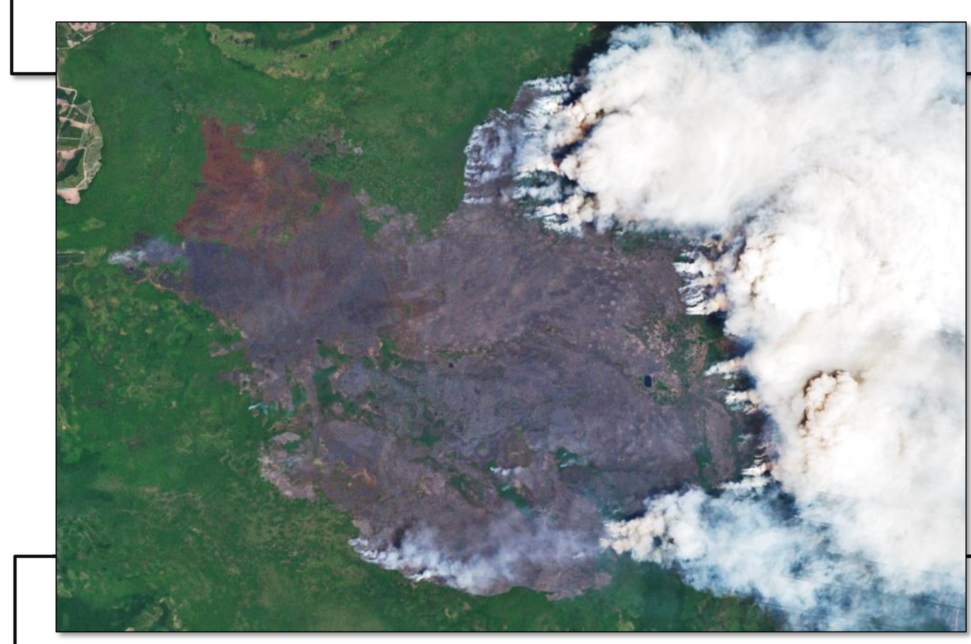
Introduction

Immediate fire effects are easier to monitor than are the longer term, often cumulative impacts from fire regimes. The 438,000 acre Okefenokee National Wildlife Refuge in Georgia, USA provides a rare opportunity to understand these differences, due to the Refuge's high productivity and frequent fires of mixed severity (A). Since 2000, large, fires have burned three times (2002, 2007 and 2011) with smaller fires occurring in other years. As in other Coastal Plain wetlands, fire severity is tied to drought intensity, as a lowered water table exposes peat to smoldering long-duration ground fire. While fire has been a part of the vegetation dynamics of the Okefenokee for millennia, both drought and large fires have increased since the late 1990s with implications for fire management, carbon sequestration, and ecological resilience.

This research demonstrates the contextual and monitoring capabilities of weekly MODIS satellite Normalized Difference Vegetation Index (NDVI) time series that capture short-term fire effects, long-term fire regime effects, and successional responses. This technology based on the US Forest Service's ***ForWarn*** system (http://www.forwarn.forestthreats.org) provides a systematic, regularly updated, tool for landscape characterization and monitoring.



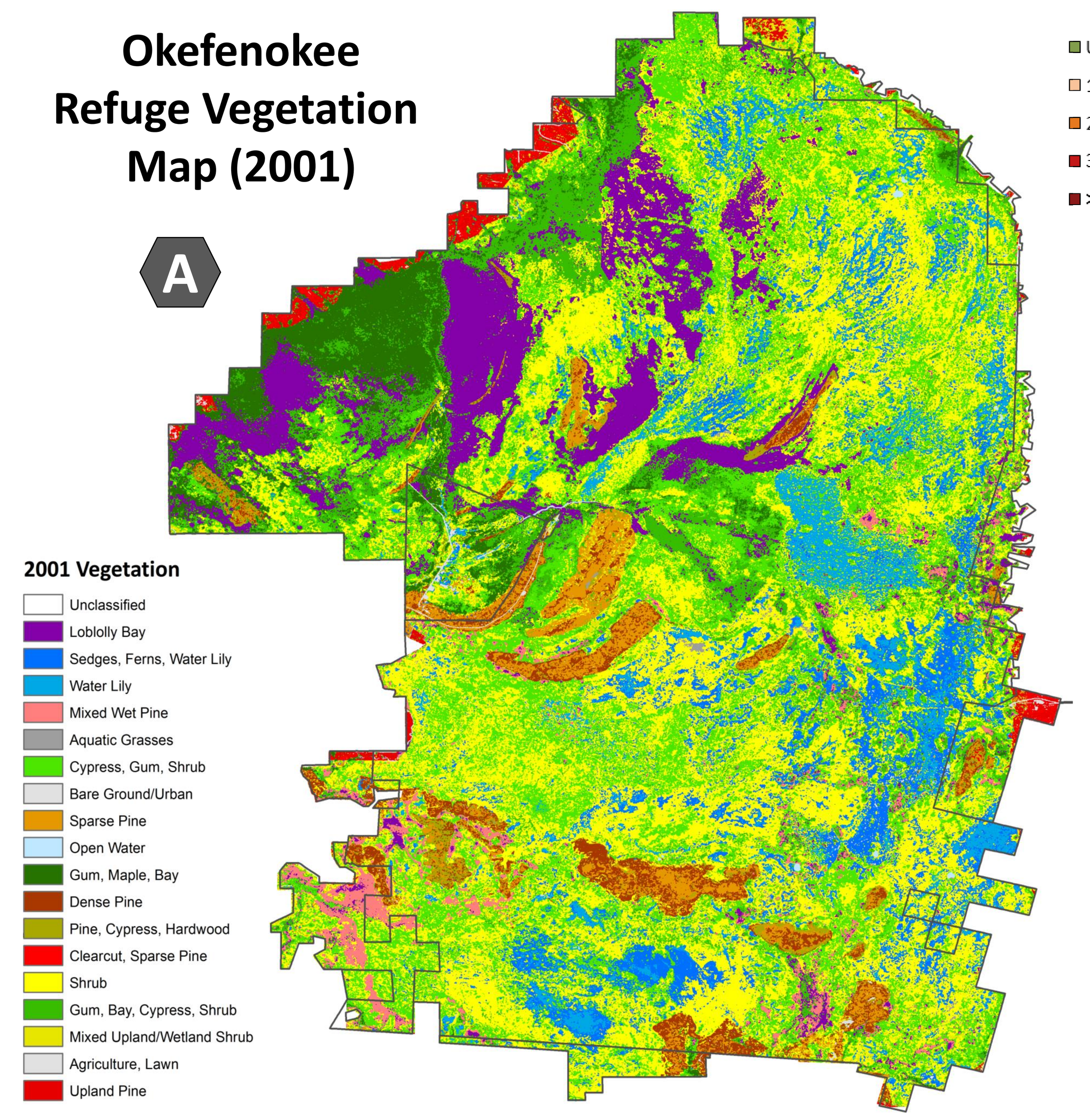
Methodology

The period of MODIS NDVI limited the temporal depth of this study to the year 2000. At that time, the Refuge had commissioned a 10m vegetation map that recognized 18 vegetation types. We calculated the majority type at MODIS resolution (232m), then further generalized these data into four types—non-pine forest, pine forest, shrub and non-woody wetlands—for analysis. Fire history for the period 2000-2013 was based on the prescribed fire and wildfire records included in the US Forest Service's Remote Sensing Applications Center Monitoring Trends in Burn Severity (MTBS) and GeoMAC databases.

ForWarn's (NDVI) 8-day time series (2000-2013) are available for every 232m pixel in the Refuge, but for this study, pixels were grouped by their majority 2001 vegetation type. This technique does not mean that the vegetation type at the end of the era was the same as the beginning, and given the mixed severity of wildfire, that is not expected. Instead, this shows how 2001 vegetation responded to local fire regimes. Vegetation types were further separated according to how many times they burned whether by wildfire or prescribed fire over the era to see if fire regimes of different frequency affected median annual NDVI between 2000 and 2013.

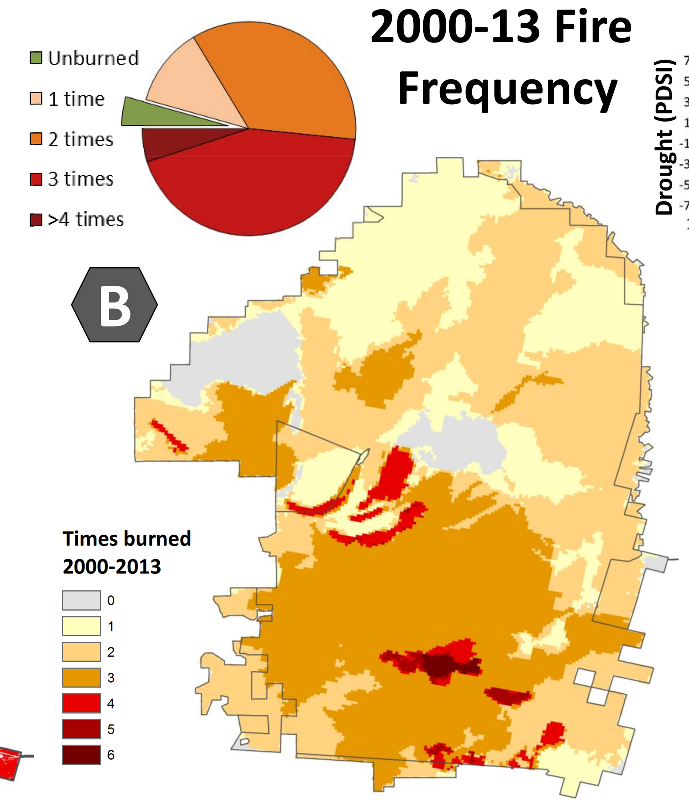
Okefenokee Refuge Vegetation Map (2001)

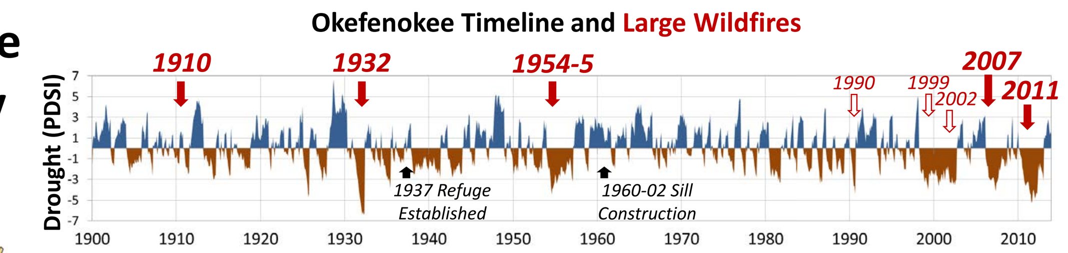
A



2000-13 Fire Frequency

B



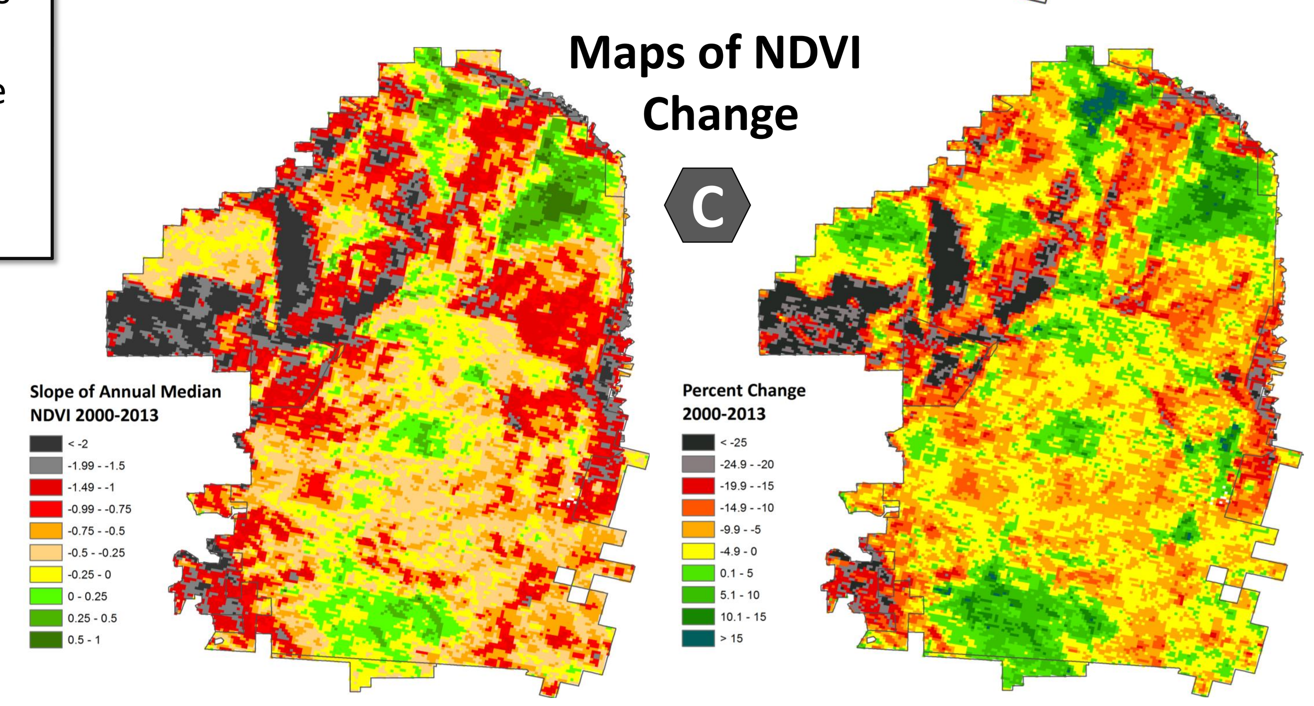


2000-2013 Fire Frequency by 2001 Vegetation Types

2001 Majority Veg Types	% of Reserve	0x burned	1x burned	2x burned	3x burned	4x+ burned
Bare Ground / Urban	0.11	18.0%	25.5%	26.8%	6.1%	23.5%
Cypress Gum Shrub	22.33	3.1%	10.4%	36.8%	49.2%	0.5%
Gum Bay Cypress Shrub	5.46	14.7%	23.5%	39.4%	21.9%	0.5%
Gum Maple Bay	2.75	57.7%	19.8%	19.8%	2.6%	0.2%
Loblolly Bay	5.63	12.0%	21.3%	55.4%	11.1%	0.2%
Pine Cypress Hardwood	0.97	0.6%	2.7%	18.2%	58.2%	20.3%
Pine Dense	3.95	0.1%	2.7%	16.1%	36.2%	44.8%
Pine Sparse	3.82	1.2%	3.4%	8.1%	25.9%	61.4%
Pine Sparse Clearcut	0.14	36.3%	29.7%	25.0%	9.0%	0.0%
Pine Upland	0.76	25.5%	33.6%	33.8%	7.1%	0.0%
Pine Wet Mixed	3.15	0.6%	3.8%	67.1%	28.4%	0.1%
Shrub	39.49	0.7%	7.7%	35.7%	54.9%	1.1%
Shrub Mixed Upland Wetland	0.31	3.9%	24.5%	25.9%	19.6%	26.1%
Aquatic Grasses	0.05	0.0%	4.4%	31.3%	56.9%	7.3%
Sedges Ferns Water Lily	6.81	0.0%	16.1%	33.0%	50.5%	0.4%
Water Lily	4.20	0.0%	40.1%	29.0%	30.8%	0.1%
Water Open	0.06	0.0%	27.0%	63.4%	9.6%	0.0%
Grand Total	100.00	**4.4%**	**12.0%**	**35.3%**	**43.3%**	**5.0%**

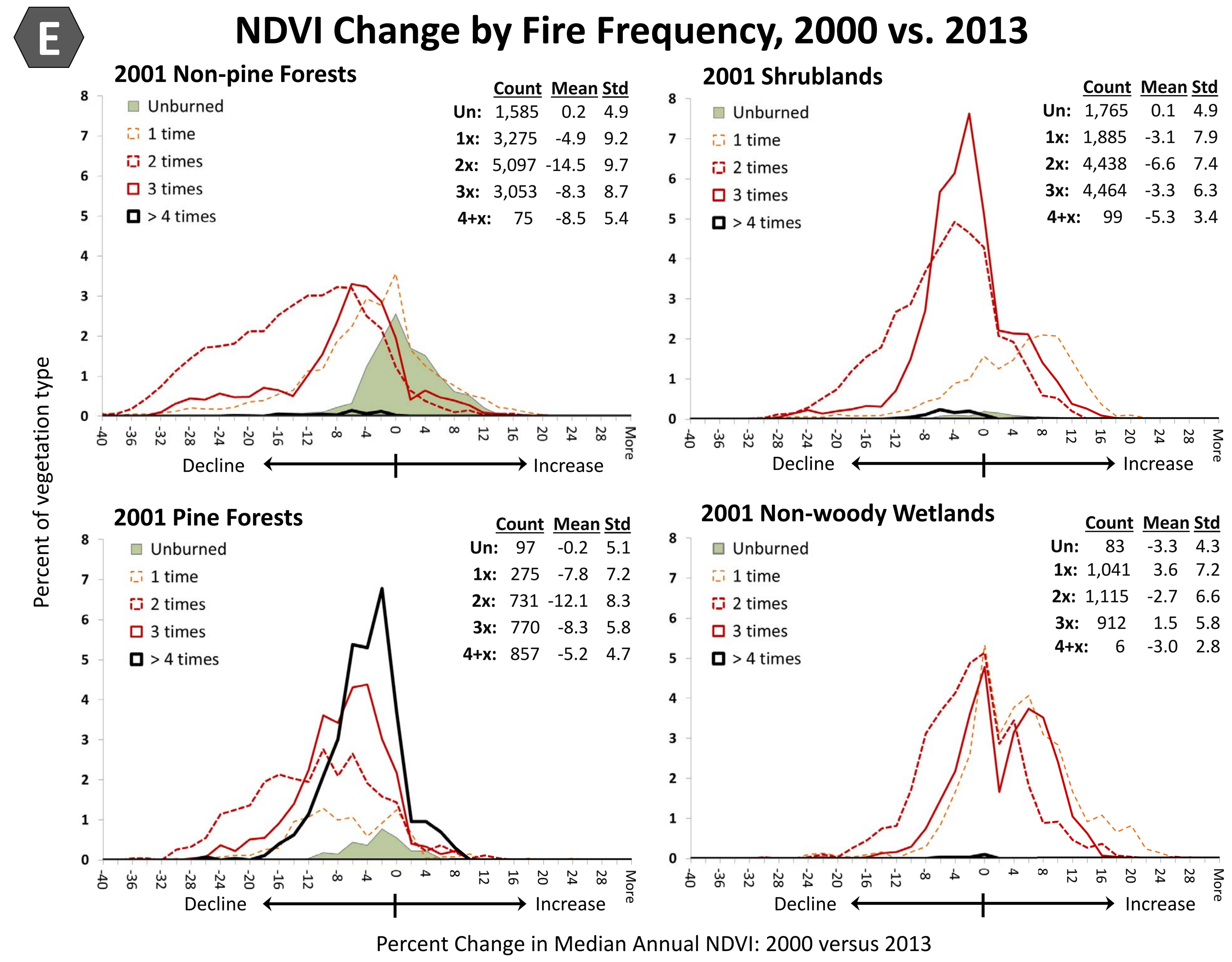
Maps of NDVI Change

C



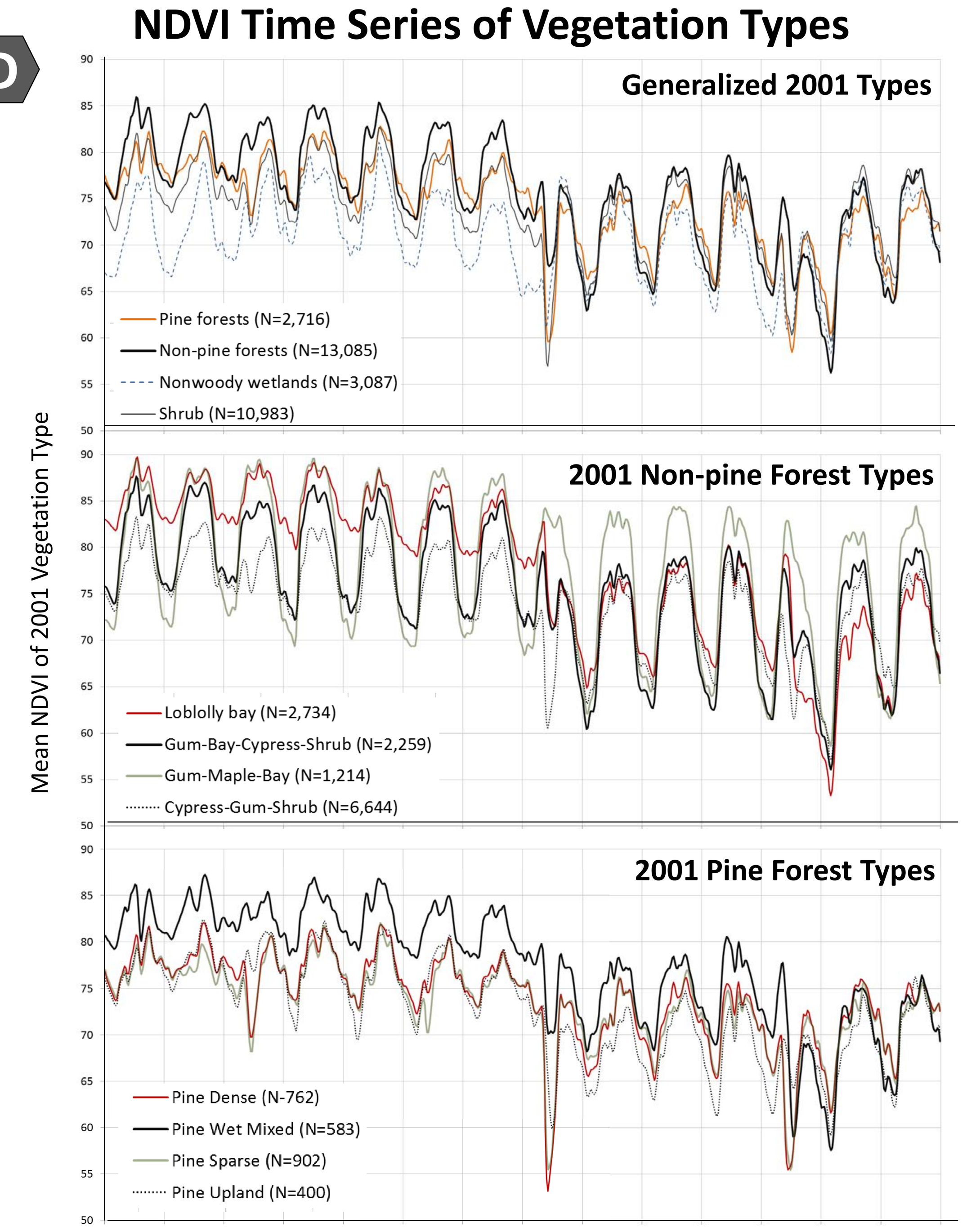
NDVI Change by Fire Frequency, 2000 vs. 2013

E



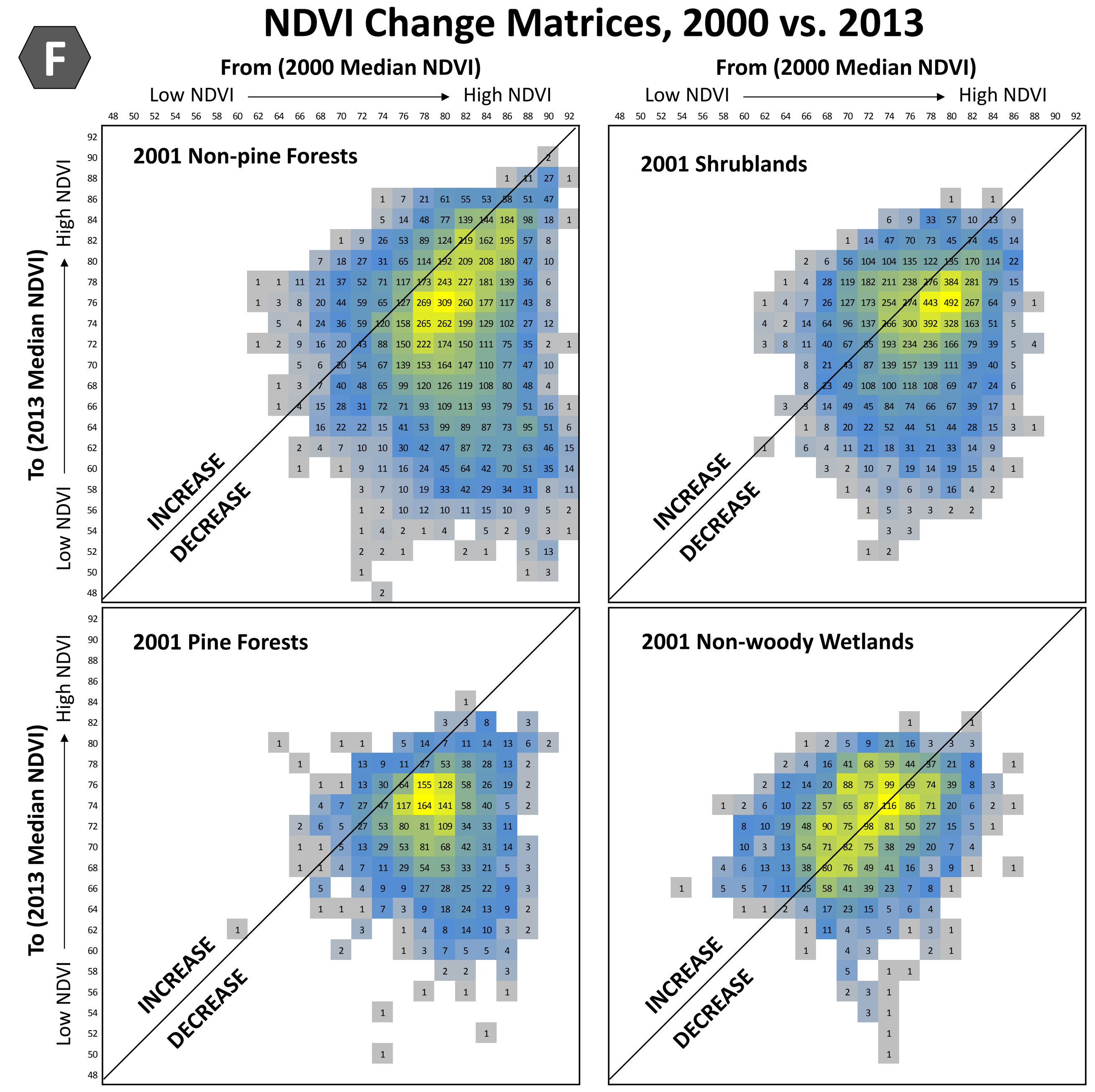
NDVI Time Series of Vegetation Types

D



NDVI Change Matrices, 2000 vs. 2013

F



Results

Nearly half of the Refuge burned three times between 2000 and 2013, with less than 5% unburned (that is, falling outside all MTBS fire perimeters) (B). Much of this was driven by the large drought-associated fires during 2007 and 2011. Pine forests burned most often because of these wildfires and active prescribed fire programs.

Whether calculated as an annual trend line or percent change (C), the Refuge exhibits mixed fire regime impacts, but a sharp net decline in median annual NDVI across all 2001 woody vegetation types including non-pine forests, pine forests, and shrublands. Non-woody wetlands appear to be the most resilient (D).

Increased fire is typically associated with a reduction in NDVI, with vegetation types that burned twice exhibiting the greatest declines (E). However, places that burned three times were more stable, with pine forests that burned four or more times exhibiting relatively minor declines. NDVI increased in shrublands and non-pine forests that went unburned, but also in non-woody wetlands that burned once and three times. While recent fire regimes have eroded NDVI overall (F), NDVI did not simply decline with more fire, as vegetation types show complex responses and evidence of frequency-mediated resilience.

Conclusions

If observed trends in drought, fire and decreasing NDVI continue, the Okefenokee Refuge may transition to an earlier successional landscape with less forest, more shrubland and more non-woody wetland. While megafires occurred episodically in the past, back-to-back megafires may be an emerging phenomenon for this system. While high frequency fire need not be erosive—as demonstrated by the relative stability of NDVI in areas that burned more frequently (E) —the drought-driven megafires of 2007 and 2011 are distinctive for their widespread cumulative erosive impacts (D). In this system, the interplay of fire event attributes and intervals is creating a complex fire regime response.

More generally, we know far less about the landscape effects of fire regimes than fire events, but monitoring tools are improving. Fire-regime monitoring needs to track not only immediate effects, but recovery, and the cumulative effects of multiple fires. While NDVI time series provide a coarse measure that is less adept at capturing details that are often required for immediate post-fire assessments, time series afford ecological and historical context that extends beyond fire events and fire perimeters. Such broadened perspectives are critical for understanding the resilience of landscapes.