Remote Sensing Technologies and the Monitoring and Management of Subalpine Summits, Acadia National Park

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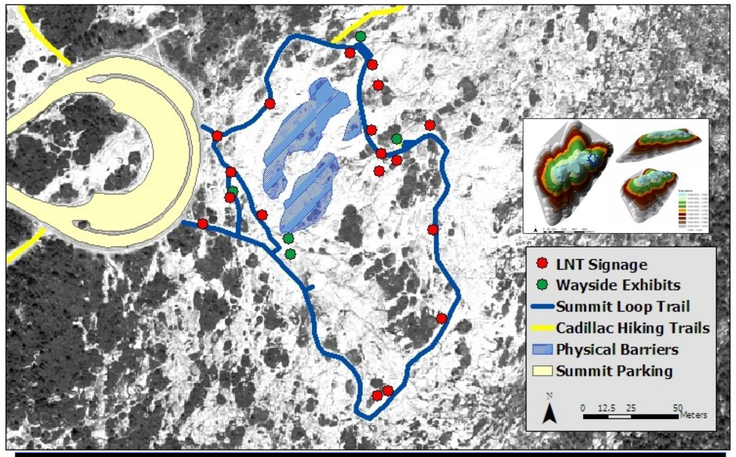
Background: Cadillac Mountain

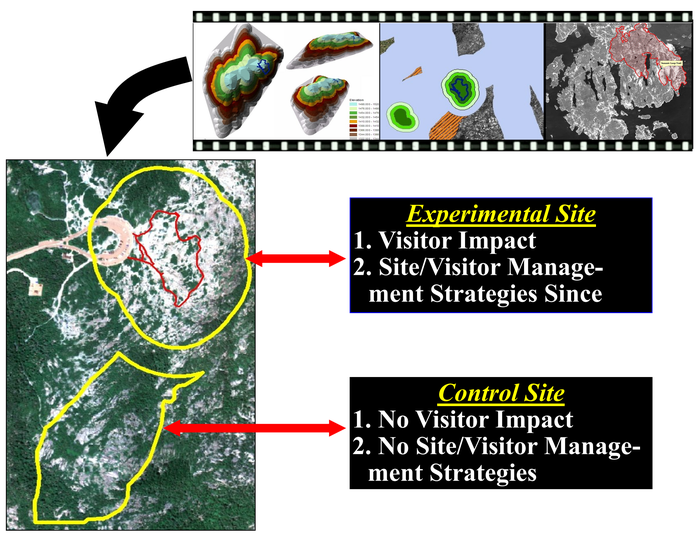
- Only mountain in Acadia National Park (ANP) with an automobile road.
- Approximately 75% of ANP visitors visit Cadillac Mountain (over 1.5 million/year).
- Extremely high visitor use in a small and sensitive area during summer.
- Slow recovery from damages caused by natural disturbance or recreational use.
- Both direct and in-direct management actions have been implemented since 2000.
- Ecological restoration project implemented in 2015.
- New vehicle reservation system implemented in 2021.



- Indirect management strategies (***red***) as signage which highlights the "Leave No Trace" principle
- Direct management strategies (***light blue***) as physical barriers (via woods/ropes)

Vegetation Cover Change Analysis

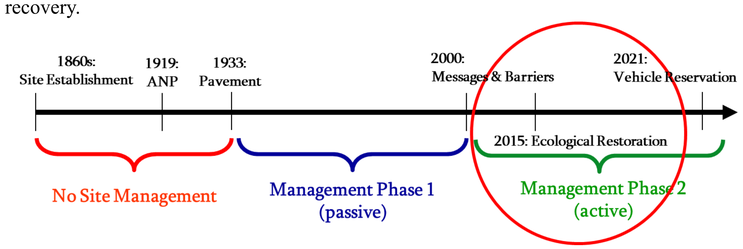
- Recreation ecology studies that have focused on vegetation change dynamics with recreational use over time have primarily concentrated on two major areas: (1) the amount of vegetation, with the impact parameter being vegetation cover, and (2) vegetation composition, with the impact parameter being species, species diversity, and frequency (Hammitt et al. 2015). Researchers have compared these measures at recreation sites (experimental) with similar measures at adjacent undisturbed sites (control) to better understand the vegetation change dynamics.



Study Objective

Direct/indirect management strategies (since 2000) Ecological Restoration Project (since 2015)

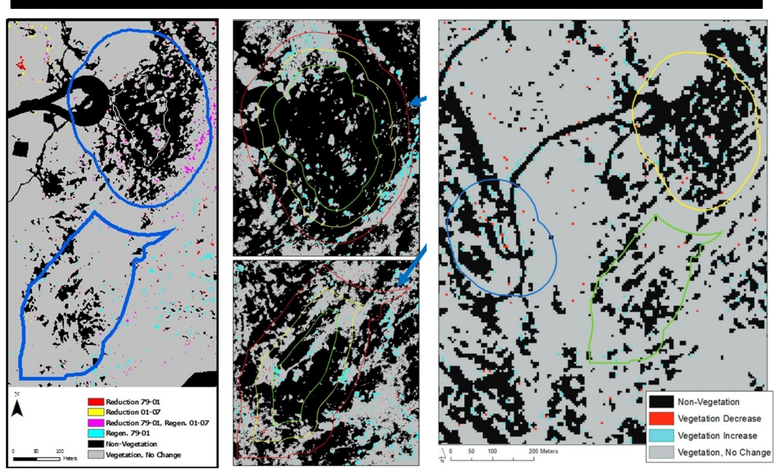
- A combination of site and visitor management strategies using physical barriers and low-impact educational messages were deployed strategically to address vegetation loss in 2000. More importantly, an ecological restoration project was newly implemented in 2015 to enhance vegetation recovery. Thus, our studies aimed to better understand vegetation change dynamics due to trampling in a fragile subalpine environment. Specific research objectives were to 1) detect direct vegetation changes resulting from visitor use by using a series of high spatial resolution remote sensing data and 2) verify the efficacy of the combined management strategies designed to reduce vegetation impact and enhance vegetation recovery.



Methodology

- **Data**: various high spatial resolution remote sensing data, including aerial photographs, NAIP, IKONOS, airborne, and Planet RapidEye (between 1979, 2001, and 2007, between 2001 and 2007, and between 2010 and 2018).
- **Vegetation cover change analysis**: Image differencing and vegetation index differencing based on the Normalized Difference Vegetation Index (NDVI) between the experimental site and the control site.
- **Image processing**: histogram matching, NDVI extraction, layer stack, and differencing & labeling (0: non-vegetation, 1: decrease, 2: increase, 3: vegetation, but no change).

Results & Discussions



Study 1: Between 1979, 2001, and 2007 | **Study 2: Between 2001 and 2007** | **Study 3: Between 2010 and 2018**

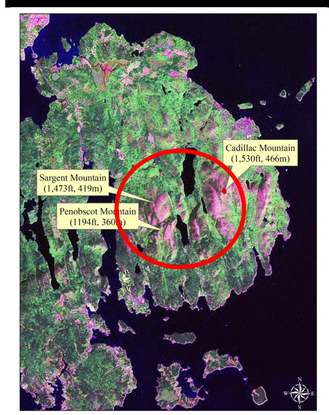
- **Results of Studies at Caillac Moutain Summits, Acadia National Park**

Spatial Scale (0-90m)		*Experimental Site (m^2)*			*Control Site (m^2)*		
		1979 - 2001	*2001 -2007*	*2010 - 2018*	*1979-2001*	*2001-2007*	*2010 - 2018*
Vegetation Decrease	Study 1	1,169	14		182	15	
	Study 2		23			180	
	Study 3			150			75
Vegetation Increase	Study 1	64	871		385	107	
	Study 2		1,668			791	
	Study 3			1,425			400

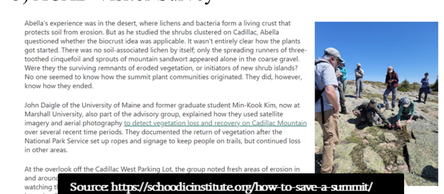
Study 1: Kim, M. K., & Daigle, J. J. (2011). Detecting vegetation cover change on the summit of Cadillac Mountain using multi-temporal remote sensing datasets: 1979, 2001, and 2007. *Environmental Monitoring and Assessment*, *180*, 63-75.
Study 2: Kim, M. K., & Daigle, J. J. (2012). Monitoring of vegetation impact due to trampling on Cadillac Mountain summit using high spatial resolution remote sensing data sets. *Environmental management*, *50*, 956-968.
Study 3: Kim, M. K., & Daigle, J. J. (2022). Long-term monitoring of vegetation cover changes by remote sensing, Cadillac Mountain summit, Acadia National Park. *Parks Stewardship Forum 38:*1.

- Before the combined management strategies (Study 1), the experimental site showed, unlike the control site, greater vegetation decrease than vegetation increase. However, the trend has changed since 2001 (both Studies 1 and 2), showing greater vegetation increase than vegetation decrease. Between 1979 and 2001, vegetation cover changes by natural variations at the control site showed greater vegetation increase and smaller vegetation decrease. In addition, between 2001 and 2007, the changes at the control site showed the same trend, greater increase, and smaller decrease. Between 2010 and 2018 (Study 3), both experimental and control sites showered greater vegetation increase than vegetation decrease. However, the amounts of both vegetation increase and decrease were higher in the experimental than in the control site.
- Given the low resilience characteristics of the subalpine environment at the summit, the trends observed (more vegetation increase and less vegetation decrease) suggest a desirable direction in terms of implementing management actions. However, continuous measurements of the vegetation condition over time will be required to assess the efficacy of the current management actions as well as to detect newly disturbed areas by visitor use and trampling. It is also expected that management recommendations could be developed for areas where the level of impact is high by measuring the recent vegetation cover changes at the summit. This information will be particularly beneficial to park/protected area managers for understanding the nature of visitor-induced impacts as well as prioritizing areas that need more intensive management.
- The vegetation cover change analyses based on remote sensing technology provide rapid and comprehensive assessments at Cadillac Mountain Summit. Due to a dense canopy cover and multiple vegetation layers, the value of remote sensing has not been well-recognized in the field of recreation ecology. However, the utility of remote sensing would be maximized in detecting vegetation cover changes, as the summit of Cadillac Mountain is an open landscape, having a mixture of sparse low-lying shrubs with bare rock dominant. Thus, this assessment method/approach could be effectively applied to other subalpine mountain summits with similar landscape conditions.

What's Next?



- **Save Our Summit (SOS) Project** with NPS, UMaine, UNLV, Navtive Plant Trust, Schoodic Institute:
  1) Ecological restoration
  2) Resource monitoring using further remote sensing data (between 2001 and 2021/2022), covering not only **Cadillac Mountain**, but also **Sargent and Penobscot Mountains**.
  3) ACAD Visitor Survey


Abella's experience was in the desert, where lichens and bacteria form a living crust that protects soil from erosion. But as he studied the shrubs clustered on Cadillac, Abella questioned whether the biocrust idea was applicable. It wasn't entirely clear how the plants got started. There was no soil-associated lichen by itself; only the spreading runners of three-toothed cinquefoil and sprouts of mountain sandwort appeared alone in the coarse gravel. Were they the surviving remnants of eroded vegetation, or initiators of new shrub islands? No one seemed to know how the summit plant communities originated. They did, however, know how they ended.

John Daigle of the University of Maine and former graduate student Min-Kook Kim, now at Marshall University, also part of the advisory group, explained how they used satellite imagery and aerial photography to detect vegetation loss and recovery on Cadillac Mountain over several recent time periods. They documented the return of vegetation after the National Park Service set up ropes and signage to keep people on trails, but continued loss in other areas.

At the overlook off the Cadillac West Parking Lot, the group noted fresh areas of erosion in and around
watching t
intensity. C
or centuries to build.

Source: https://schoodicinstitute.org/how-to-save-a-summit/