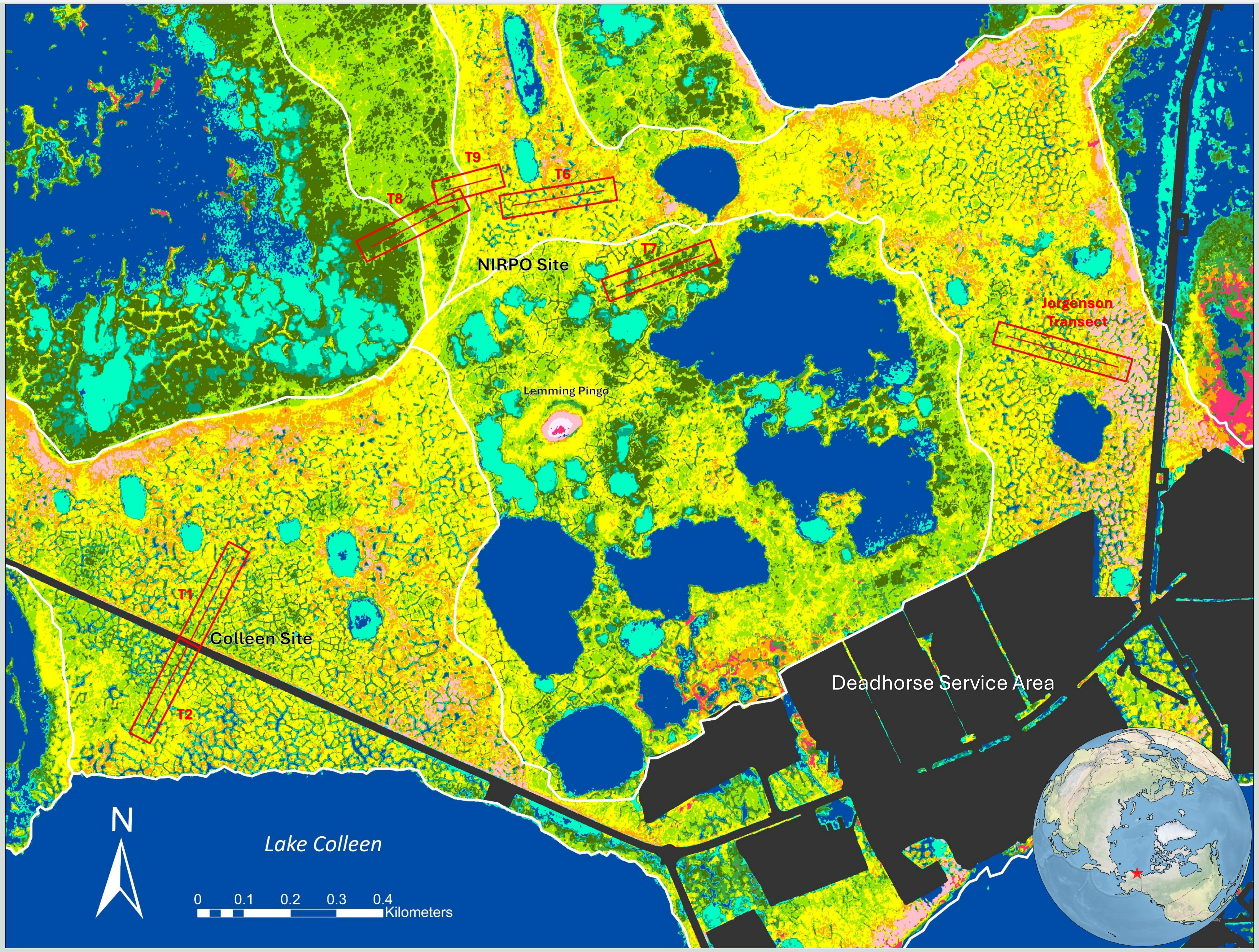
High-resolution classified vegetation map of evolving ice-wedge-polygon terrain, Prudhoe Bay, Alaska

Olivia Hobgood, Donald Walker, Martha Raynolds, Amy Breen, Julia White, Santosh Panda



D. Dry Non-Acidic Tundra

D1. Dry non-acidic tundra on cold, windblown, gravelly sites.

Present on very well-drained sites such as upper pingo slopes and exposed river bluffs. Dominated by prostrate evergreen shrubs, xeric sedges, mat and cushion forbs, and a variety of crustose lichens.

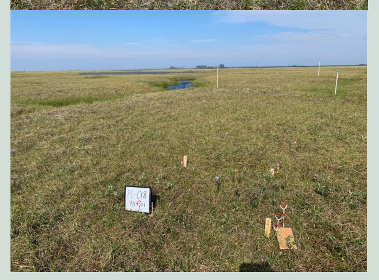
D2. Dry non-acidic tundra on fine-grained, organic-rich soils.

Present on moderately well-drained sites such as lower pingo slopes, high-centered polygons, and exposed lake and river bluffs. Dominated by prostrate dwarf shrubs, sedges, a variety of forbs, and mosses.

M. Moist Non-Acidic Tundra

M1. Moist non-acidic tundra with abundant lichens.

Present on mesic sites such as high- and flat-centered polygons in addition to some raised rims. Dominated by non-tussock sedges, prostrate dwarf shrubs, a variety of mosses, and some lichen species.



M3. Moist non-acidic tundra with few lichens.

Present on mesic to hygro-mesic sites such as flat-centered polygons, hummocks, disjunct rims, and well-drained low-centered polygon basins. Dominated by sedges, prostrate dwarf shrubs, and mosses.

W. Wet Non-Acidic Tundra

W1. Wet calcareous fen with intermittent standing water.

Present on saturated and seasonally inundated sites such as featureless drained lake basins and low polygon centers with organic, peaty soils. Dominated by basiphilous sedges and mosses.

W2. Very wet calcareous fen with shallow standing water.

Present on saturated and perpetually inundated sites such as deeper featureless drained lake basins low polygon centers. Species-poor, often covered partially by marl. Dominated by sedges and mosses.

A. Aquatic Vegetation

A1t. Transitional aquatic vegetation dominated by productive sedges.

Present in recently submerged sites, most commonly along the edges of subsiding ice-wedge polygon troughs. Dominated by lush, productive sedges and abundant mosses. Aquatic forbs sometimes present.

A1. Aquatic sedge marsh.

Present in minerotrophic sites such as shallow ponds and lake margins. Has thick, highly organic soils with dense fibrous roots that are covered by marl. Dominated by sparse sedges and some moss species. Aquatic forbs are sometimes present.

L. Lakes and Ponds

L2. Shallow ponds and lakes with marl-covered bottoms.

This unit indicates shallow water underlain by a layer of marl, a mixed carbonate and organic sediment. Although mostly unvegetated, it may contain sparse emergent or submerged aquatic vegetation.

L1. Deeper lakes and ponds with minimal visible vegetation.

This unit indicates deeper water where the bottom is not clearly visible. Although mostly unvegetated, it may contain sparse emergent or submerged aquatic vegetation which was not resolved during training.

Zoogenic Enriched Vegetation

This unit encompasses several vegetation types across the moisture gradient, all of which are nutrient-enriched by human or animal activity. They are typically grass- and moss-dominated and often contain several unique forb species. Includes dry pingo tops, moist bird mounds and animal middens, and wet areas enriched by leaky sewage ponds.

Anthropogenic Infrastructure

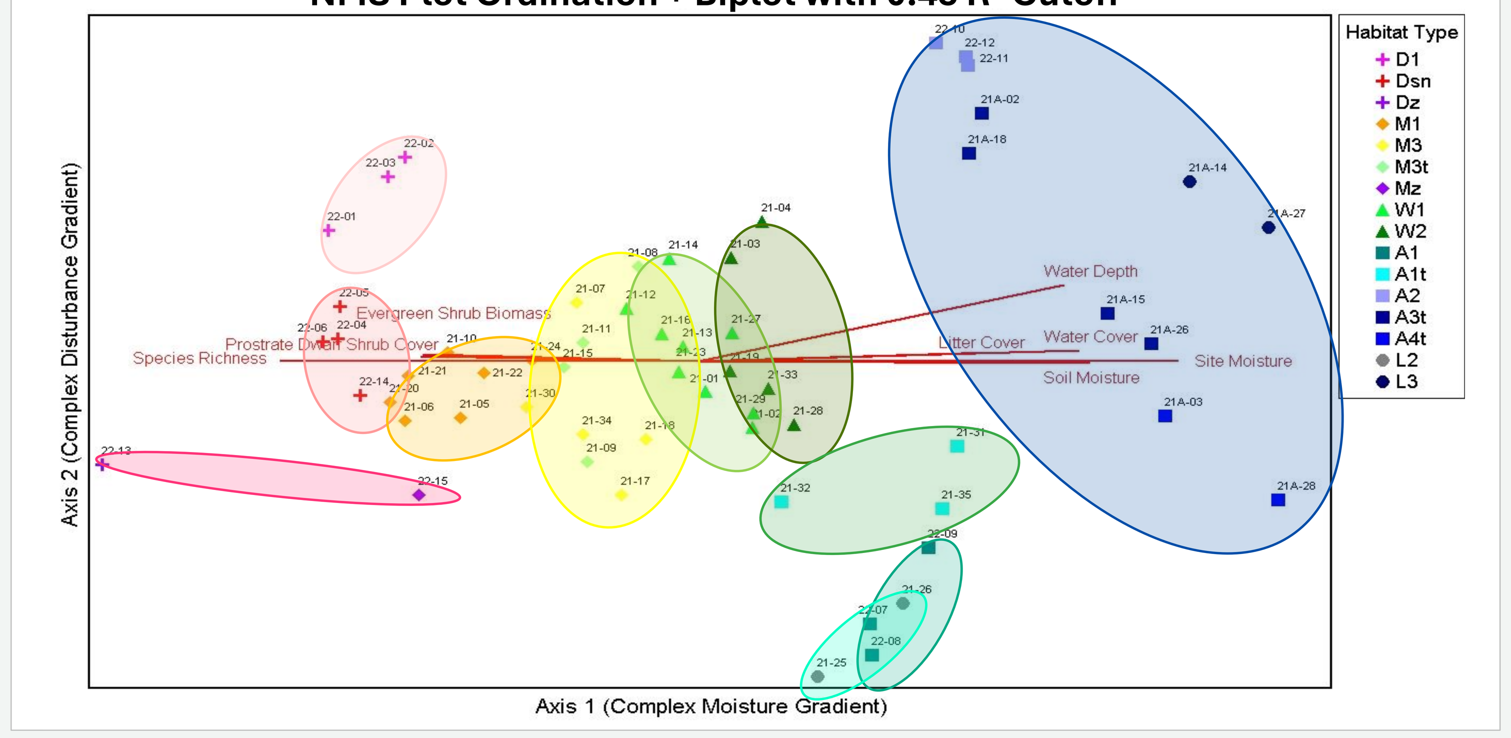
This unit indicates where oil field infrastructure is present. This includes roads, pipelines, gravel pads, and buildings. Some types of infrastructure were difficult to distinguish spectrally from dry marl. Infrastructure was masked out by hand before the random forest classification, then added back as a separate class afterwards.

Vegetation Methods

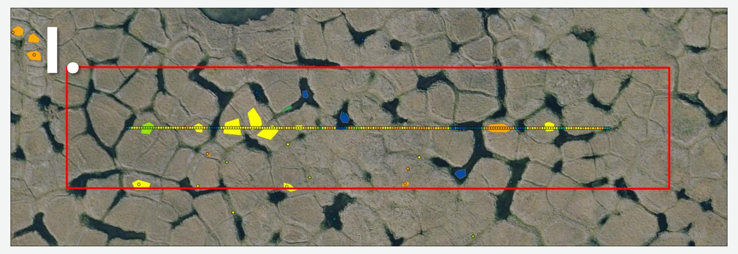
Vegetation was sampled along and around seven permanent vegetation monitoring transects (shown above) using Braun-Blanquet sampling protocols [1]. Species over-abundance scores and a suite of environmental variables were recorded at each 1 m^2 monitoring plot [2].

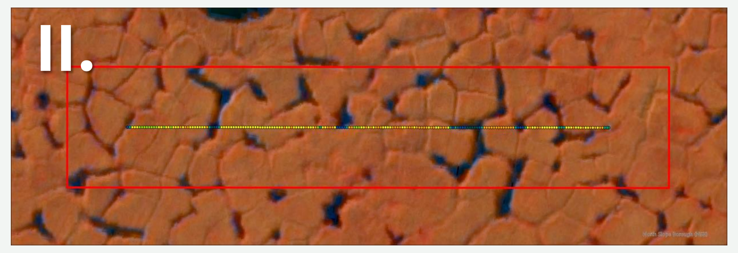
The NMS ordination below shows the relationship between the plots based on their species composition [3]. Increasing distance between plots indicates decreasing species similarity. The red vectors indicate strong correlations with environmental variables. Color-coded ovals are drawn over the groups mapped. This figure indicates that the units mapped are both clearly separable by species composition and strongly associated with the moisture gradient.

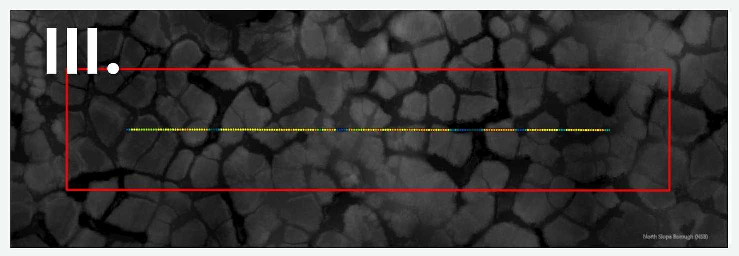
NMS Plot Ordination + Biplot with 0.45 R^2 Cutoff

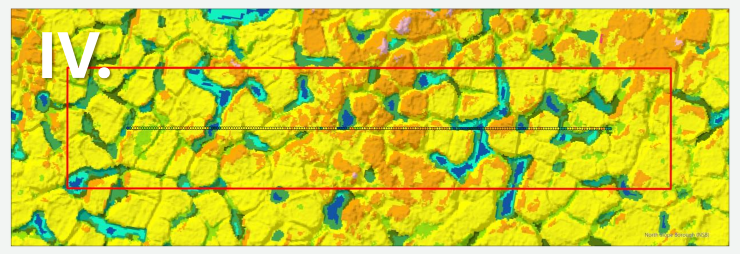


Classification Methods









Classification was performed in ArcGIS Pro. The layers shown over transect 6 illustrate the primary steps.

(I.) Training samples were drawn on a high-resolution aerial photograph acquired from BP over homogenous areas surrounding existing vegetation plots.

(II.) 0.5-m pansharpened multispectral WorldView-02 imagery acquired through the Polar Geospatial Center was normalized by the brightness of each pixel [4].

(III.) A "microrelief" layer was derived from a 0.25 m DEM obtained from the Alaska Division of Geological & Geophysical Surveys by subtracting a 50 m minimum aggregate of the DEM from the original layer.

(IV.) The imagery and microrelief layer were stacked and input along with the training samples to train a random forest classifier [5]. The classified output was generalized to remove small, noisy patches of units.

An accuracy assessment was performed by evaluating 372 randomly generated points within 2 m^2 apparently homogenous areas on the ground. The points were stratified relative to the prevalence of each unit, though rare types were oversampled relative to their occurrence. The overall accuracy of the map is 69.6%.

Key Takeaways

- This map demonstrates an effective method for high-resolution vegetation mapping in the Arctic which may be extended to larger areas and regions.
- The use of the DEM-derived "microrelief" raster drastically improved the accuracy of the classification due to the strong demonstrated relationship between vegetation, moisture, and microrelief in the region.
- This map illustrates the spatial association between vegetation, ground ice features, and the relative ice richness of differently-aged surfaces. Some transitional vegetation can be identified.

Further Reading

[1] Westhoff, Victor, and Eddy Van Der Maarel. (1978). "The Braun-Blanquet Approach." In Classification of Plant Communities, edited by Robert H. Whittaker, 287–399. Classification of Plant Communities. Dordrecht: Springer Netherlands.
[2] Walker, D.A., M. Kanevskiy, A.L. Breen, A.N. Kade, R.P. Daanen, ... and J.L. Pierce. (2022). Observations in ice-rich permafrost systems, Prudhoe Bay Alaska, 2020-21. Alaska Geobotany Center Data Report AGC22-01, Institute of Arctic Biology, University of Alaska Fairbanks, USA.
[3] Kruskal, J.B. and Wish, M. (1978). Multidimensional Scaling. Sage University Paper Series on Quantitative Applications in the Social Sciences, No. 07-011, Sage Publications, Newbury Park.
[4] Wu, C. (2004). Normalized spectral mixture analysis for monitoring urban composition using ETM+ imagery. Remote Sensing of Environment 93:480–492.
[5] Esri. (2023). Forest-based Classification and Regression (Spatial Statistics). https://pro.arcgis.com/en/pro-app/3.1/tool-reference/spatial-statistics/forestbasedclassificationregression.htm

Acknowledgements

This work was funded by NSF award no. 1928237. I would like to give special thanks to my advisor, Dr. Skip Walker, for always giving me expert advice; to Julia White, who made the accuracy assessment possible; to Dr. Santosh Panda, who helped me refine the methods, to Jana Pierce, who helped with graphic design; and finally to my partner, Rowan Biessel, for moral support and late-night coffee.