Leveraging satellite observations for freshwater monitoring on Cape Cod

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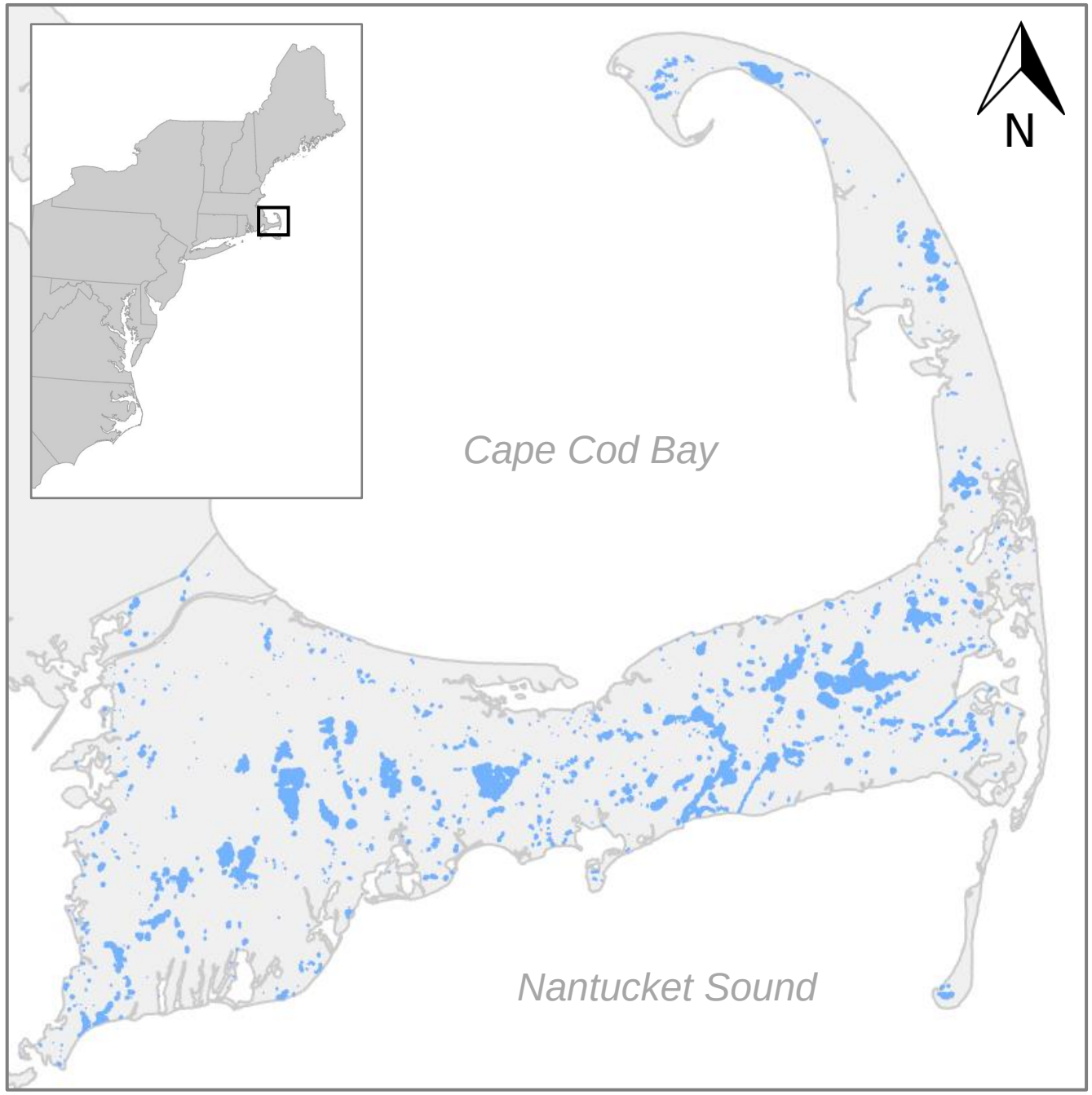
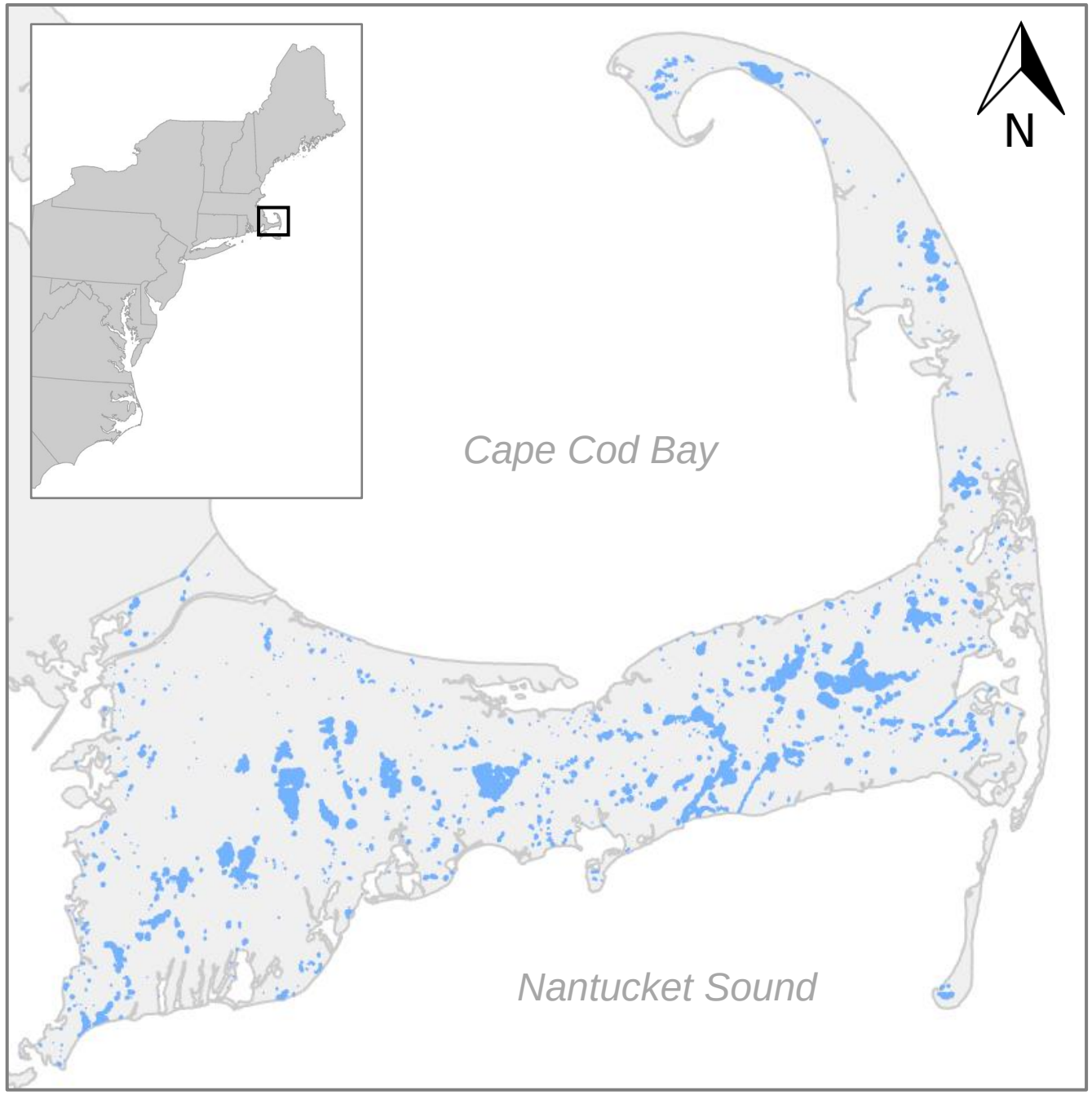


890

ponds across the Cape, which provide nitrogen filtering capacity and offer recreational and ecological opportunities

Cape Cod Commission, 2021; *Pond & Lake Atlas*



90%

of the Cape's ponds had insufficient data to assess water quality status in 2021

Cape Cod Commission, 2021; *Pond & Lake Atlas*

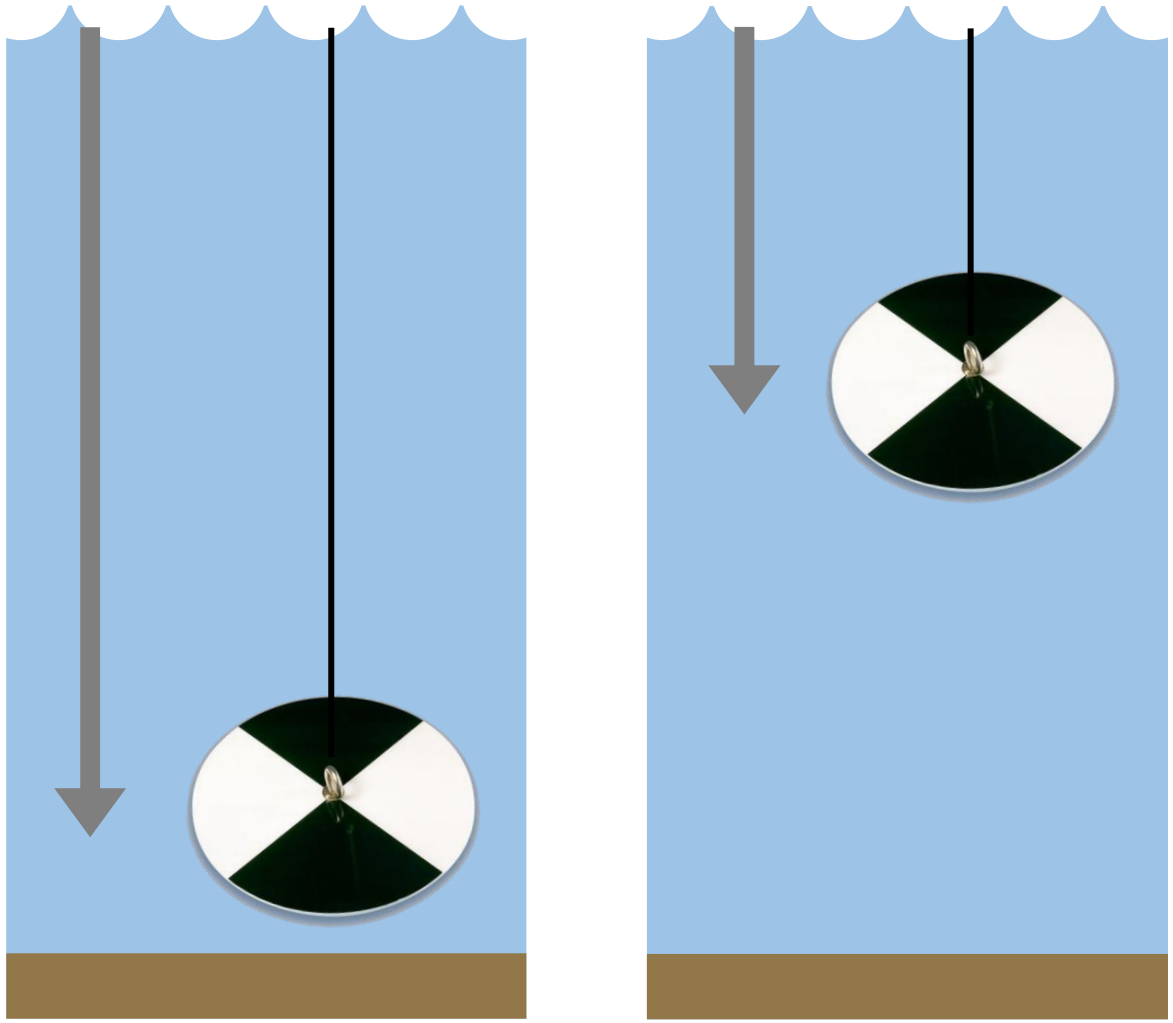
Use satellite imagery to predict Secchi disk depth by analyzing its relationship with field-measured Secchi disk depth

Assess long-term changes in Secchi disk depth across Cape Cod as an indicator of changing water clarity over time

Cape Cod Commission *(CCC) has Secchi disk depth for* ***217 ponds*** *(data collected intermittently from* ***2001-2022****)*

Data are from both ***citizen science*** *programs and* ***municipality monitoring*** *efforts across the Cape's 15 towns*

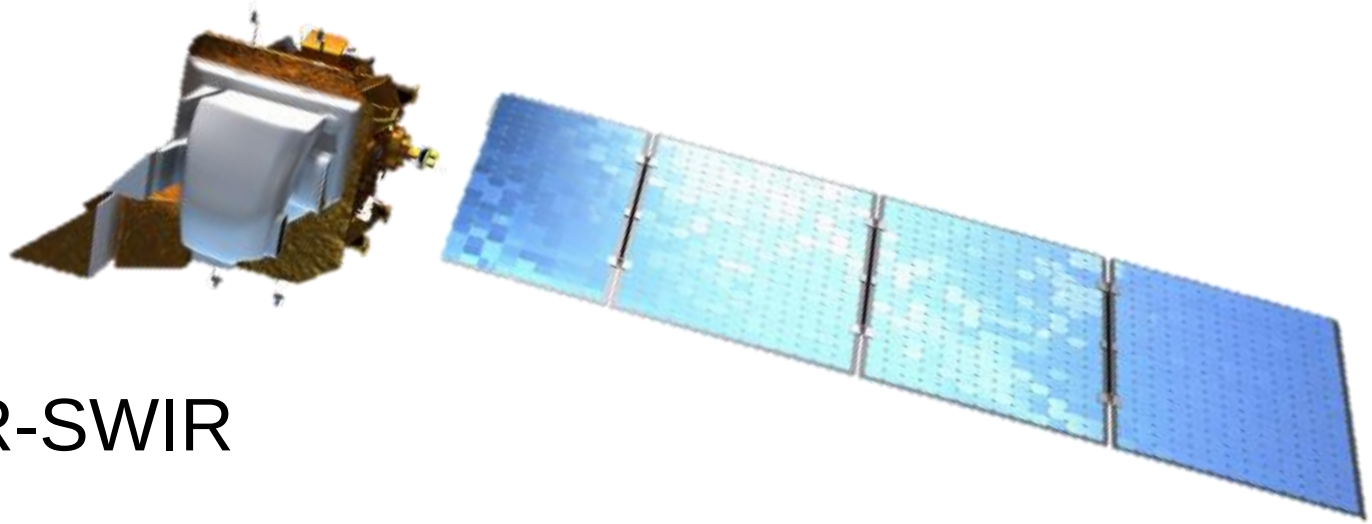
CCC also provides maximum ***pond depth*** *for approximately* ***200 ponds***



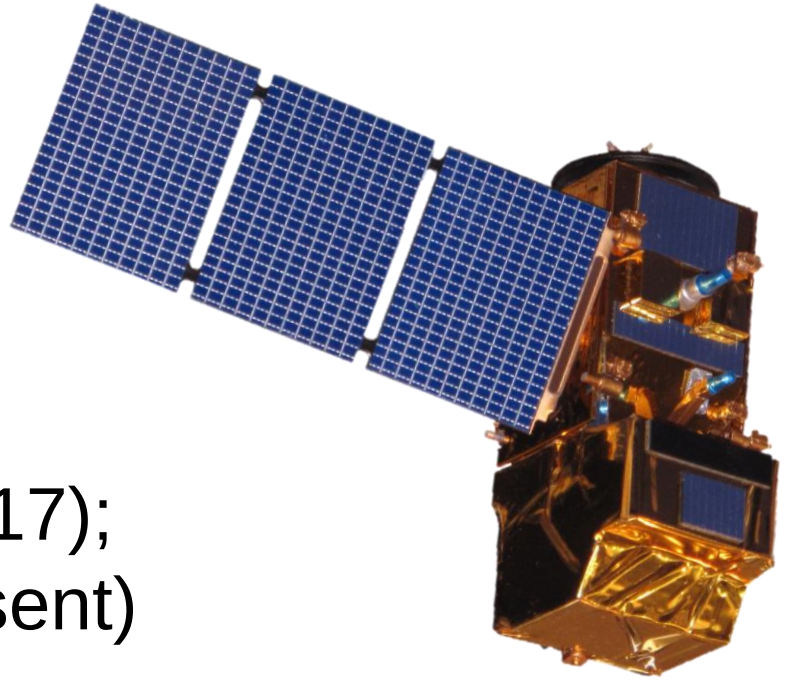
Better water clarity

Worse water clarity

USGS & NASA's Landsat 8
Lifespan: 2013-present
Spatial resolution: 30 m
Spectral resolution: 4 VIS, 3 NIR-SWIR
Temporal resolution: 16 days



ESA's Sentinel-2A and -2B
Lifespan: 2015-present
Spatial resolution: 20 m
Spectral resolution: 7 VIS, 5 NIR-SWIR
Temporal resolution: 10 days (2015-2017);
5 days (2017-present)



Extract satellite data corresponding to field measurements

Generate a random forest algorithm to predict Secchi disk depth

Assess trends in water clarity using satellite-estimated Secchi disk depth

Google Earth Engine

*Satellite measurements collected within **4 days** of field data were **averaged** within a **10 m** buffer of each Secchi disk depth location*

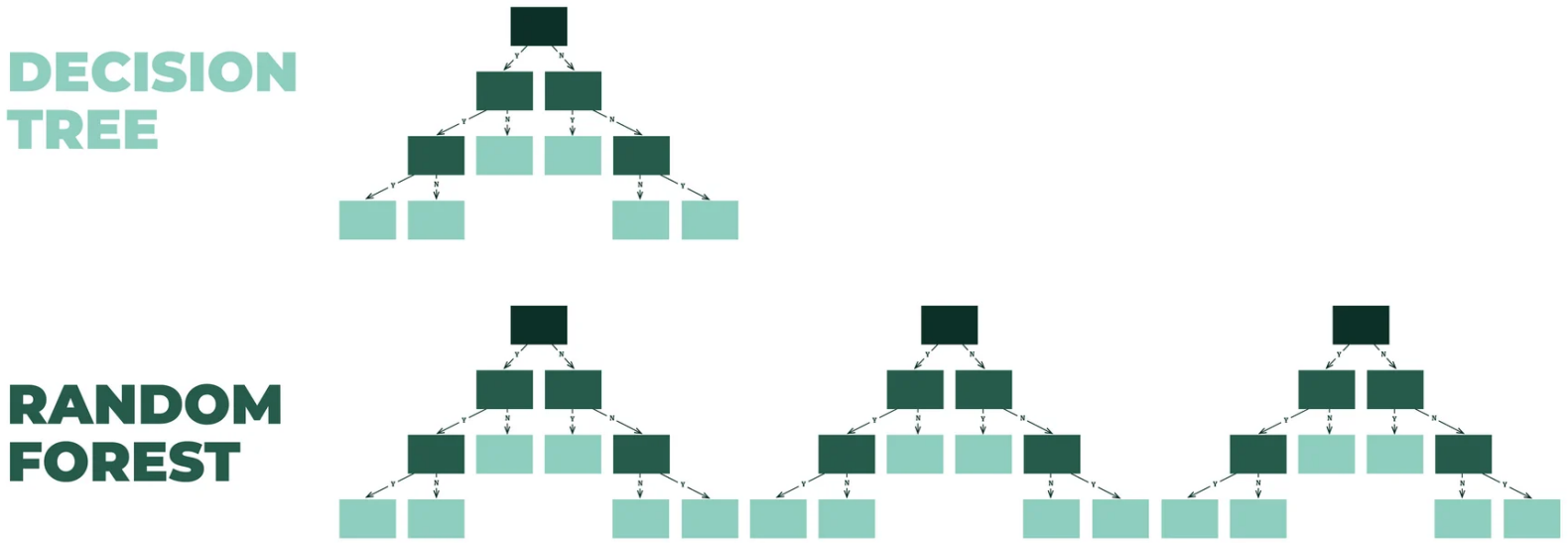
Extract satellite data corresponding to field measurements

Generate a random forest algorithm to predict Secchi disk depth

Assess trends in water clarity using satellite-estimated Secchi disk depth

Random forest

Generated to predict Secchi disk depth using satellite reflectance;
*the **inclusion of pond depth** was tested*



Extract satellite data corresponding to field measurements

Generate a random forest algorithm to predict Secchi disk depth

Assess trends in water clarity using satellite-estimated Secchi disk depth

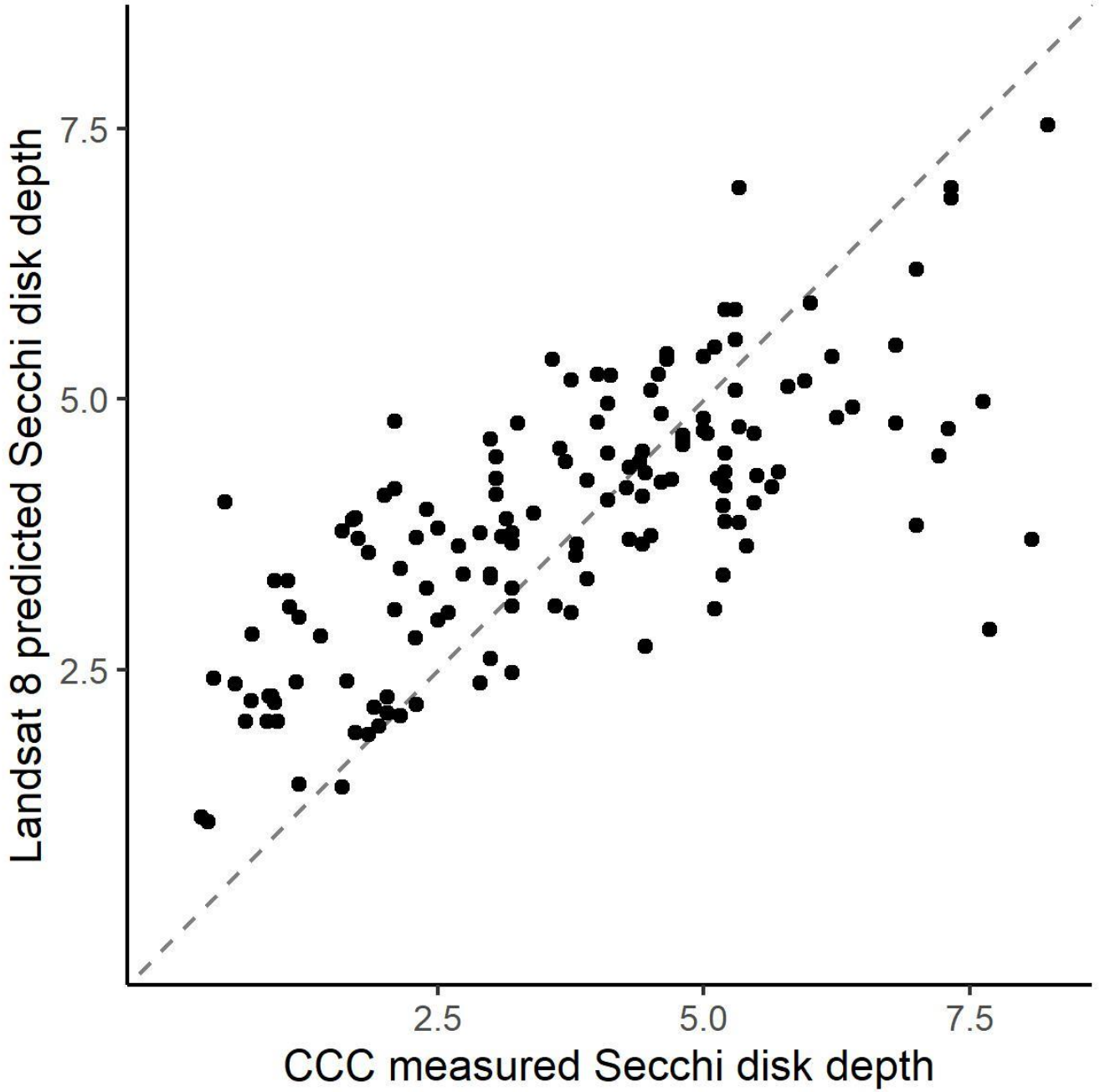
Mann Kendall test for trend

Using Landsat 8, ***average summer*** *Secchi disk depth from* ***2013-2022*** *was assessed (10-year time period)*

180 ponds *assessed as they had a depth measurement and at least 4 years of satellite data*

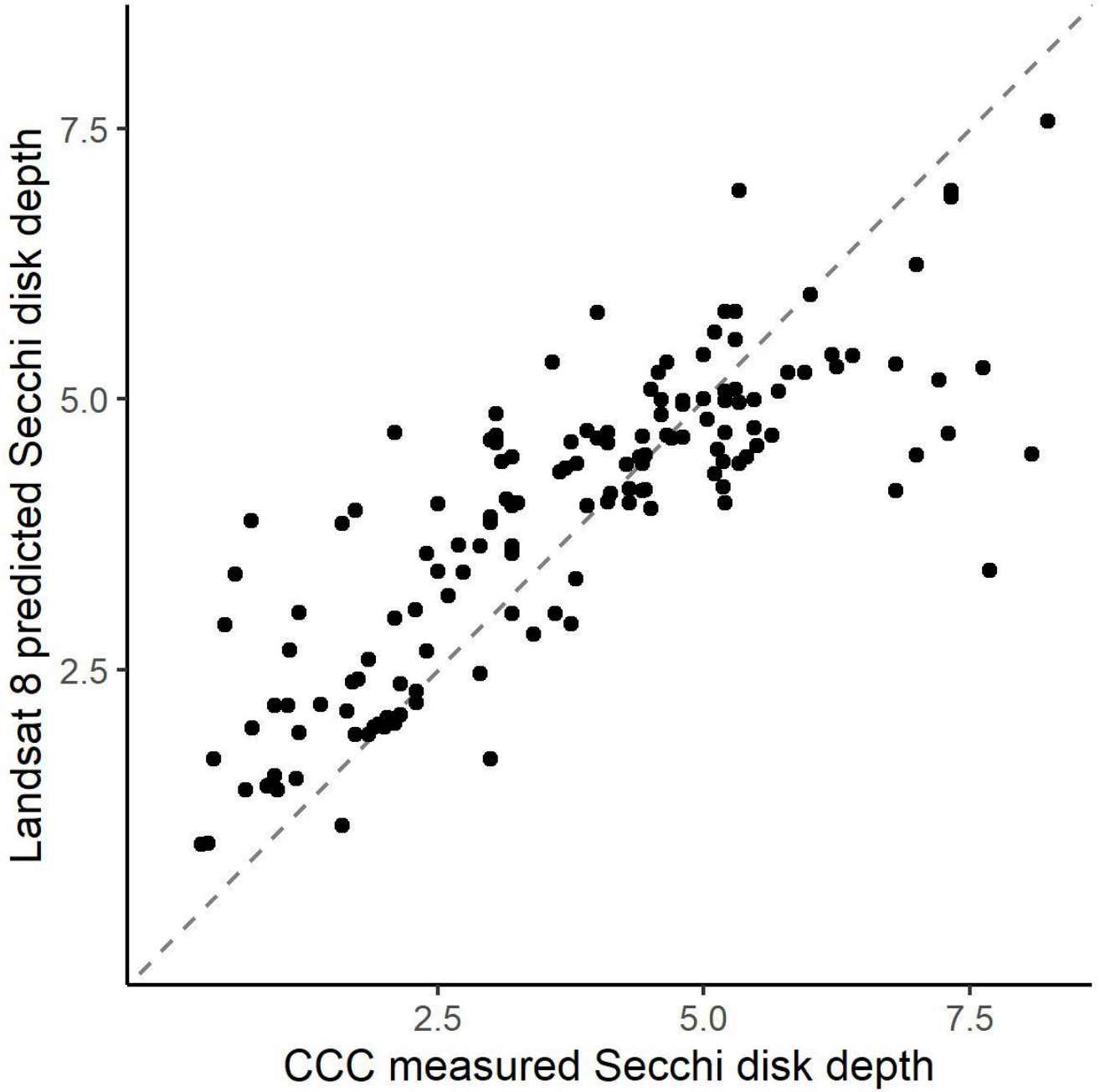
Use satellite imagery to predict Secchi disk depth by analyzing its relationship with field-measured Secchi disk depth

Assess long-term changes in Secchi disk depth across Cape Cod as an indicator of changing water clarity over time



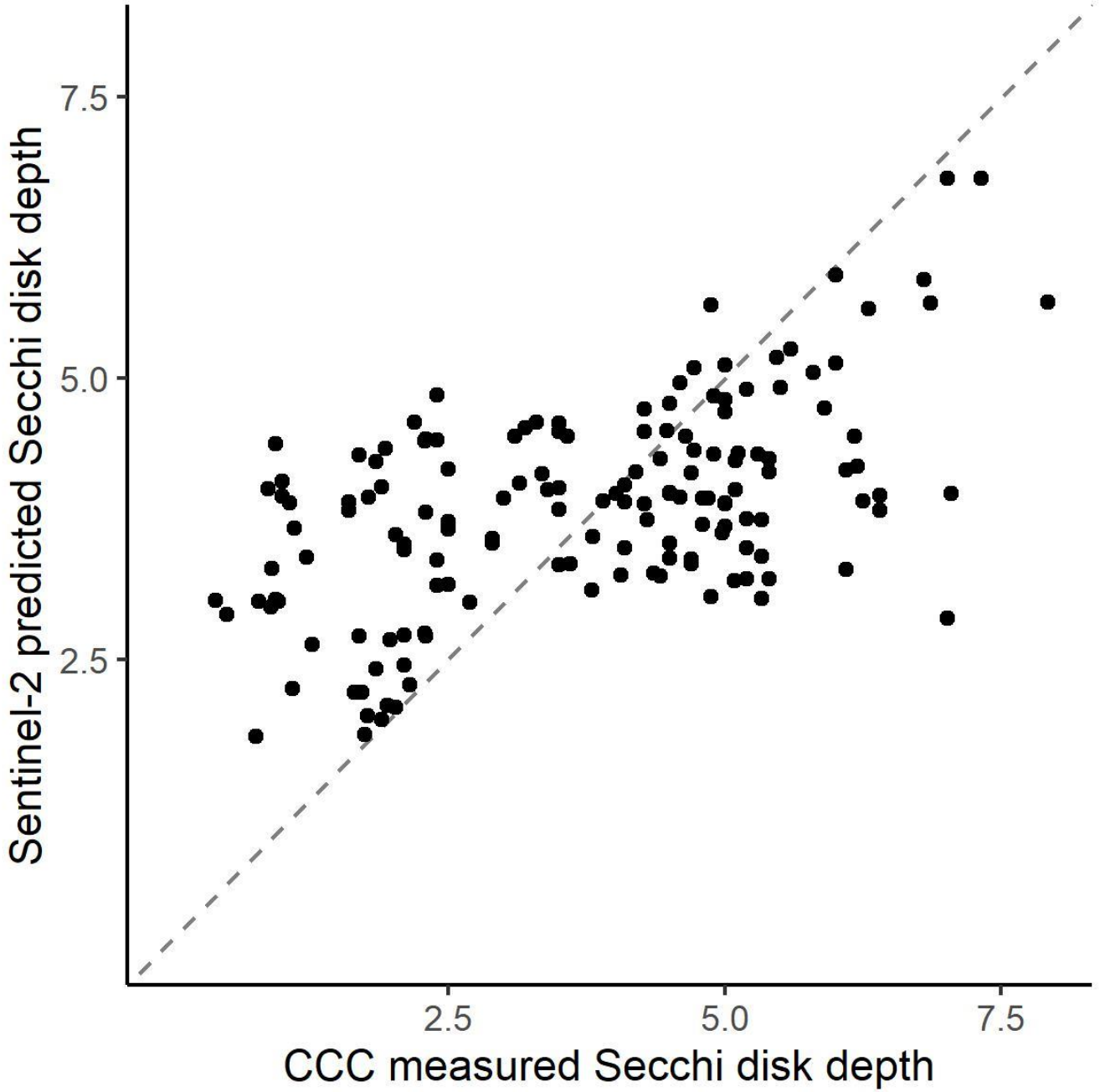
Excluding pond depth *as a predictor variable, Secchi disk depth predicted with* ***Landsat 8*** *had* ***moderate agreement*** *with field data (Spearman rank correlation coefficient = 0.73)*

High variability; disagreement at ***deeper field-measured*** *Secchi disk depths*



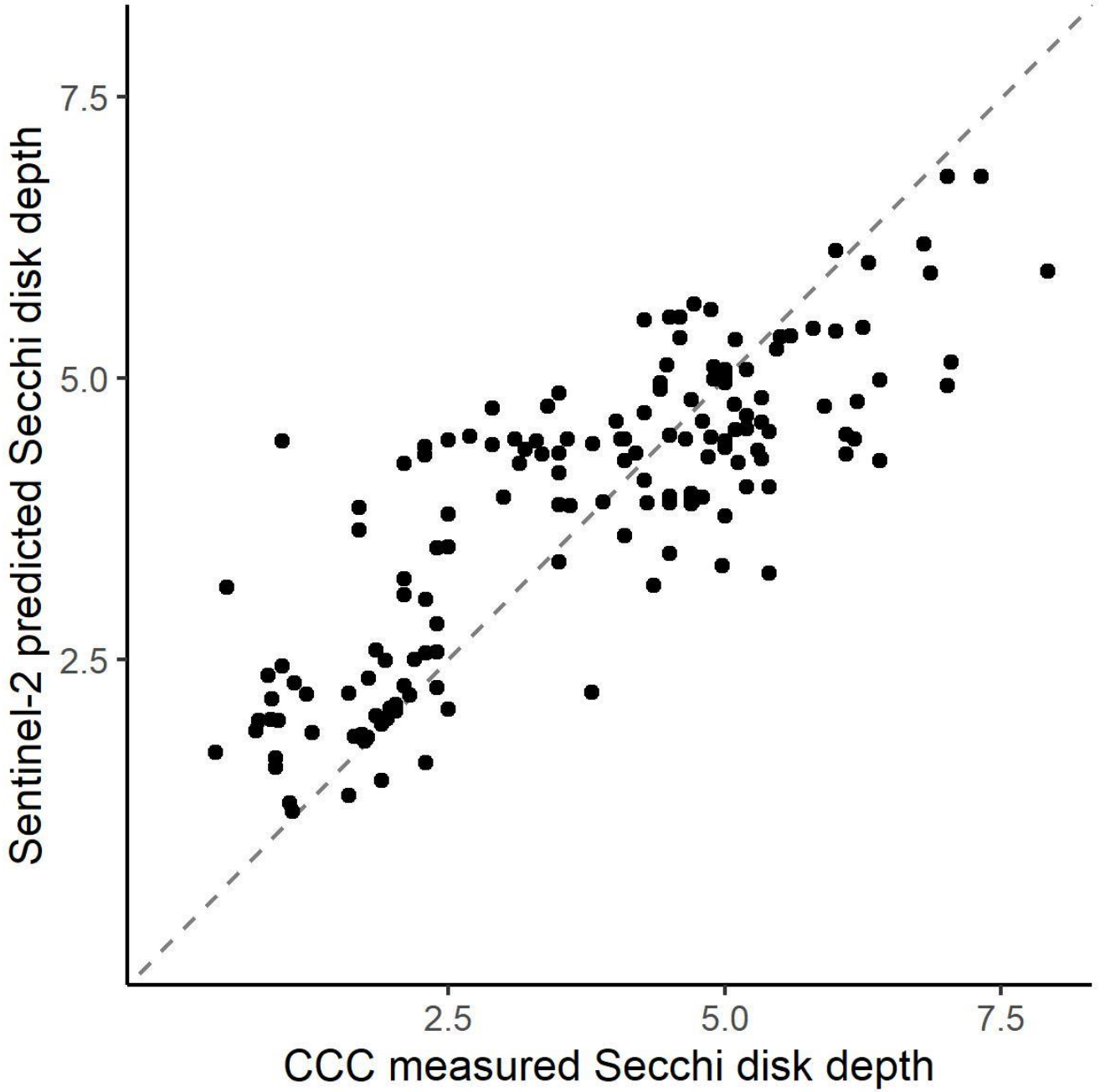
Including pond depth *as a predictor variable, Secchi disk depth predicted with* ***Landsat 8*** *had* ***strong agreement*** *with field data (Spearman rank correlation coefficient = 0.84)*

Disagreement primarily at ***deeper field-measured*** *Secchi disk depths*



Excluding pond depth *as a predictor variable, Secchi disk depth predicted with* ***Sentinel-2*** *had* ***low agreement*** *with field data (Spearman rank correlation coefficient = 0.49)*

Overpredicts at low *Secchi disk depths;* ***underpredicts at high*** *Secchi disk depths*



Including pond depth *as a predictor variable, Secchi disk depth predicted with* ***Sentinel-2*** *had* ***strong agreement*** *with field data (Spearman rank correlation coefficient = 0.80)*

Higher variability; but ***better at predicting deeper Secchi disk depths***

Satellite performance

Landsat 8 performed marginally better than Sentinel-2

The increased temporal resolution of Sentinel-2 is likely less important for management purposes than the slightly longer time series offered by Landsat 8

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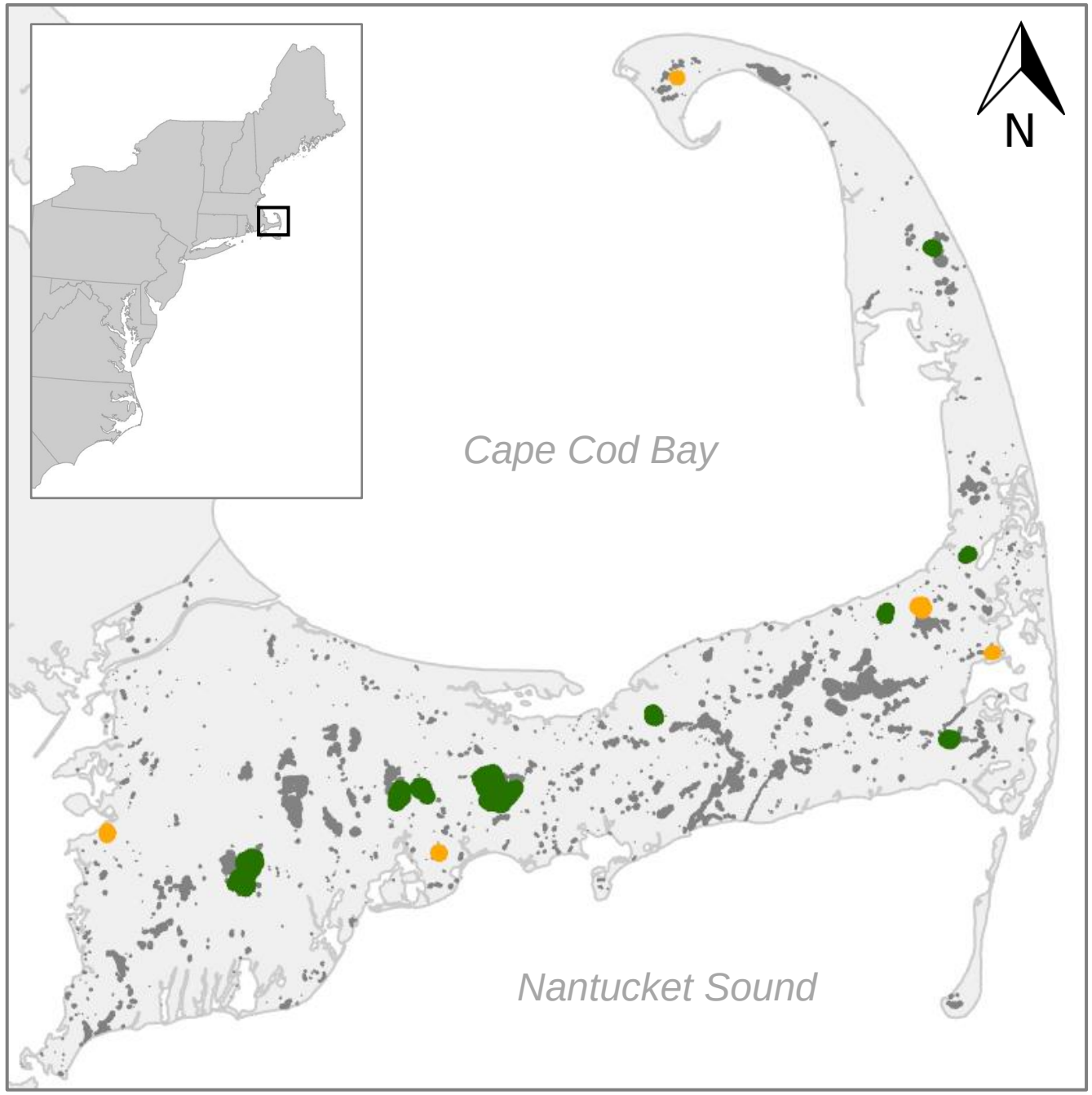
Pond depth

Both satellites showed a noticeable improvement in their predictive capability after including maximum pond depth as a predictor variable

Pond depth is not available across all ponds in Cape Cod, which limits the availability of data for model training and thus limits the applicability

Use satellite imagery to predict Secchi disk depth by analyzing its relationship with field-measured Secchi disk depth

Assess long-term changes in Secchi disk depth across Cape Cod as an indicator of changing water clarity over time

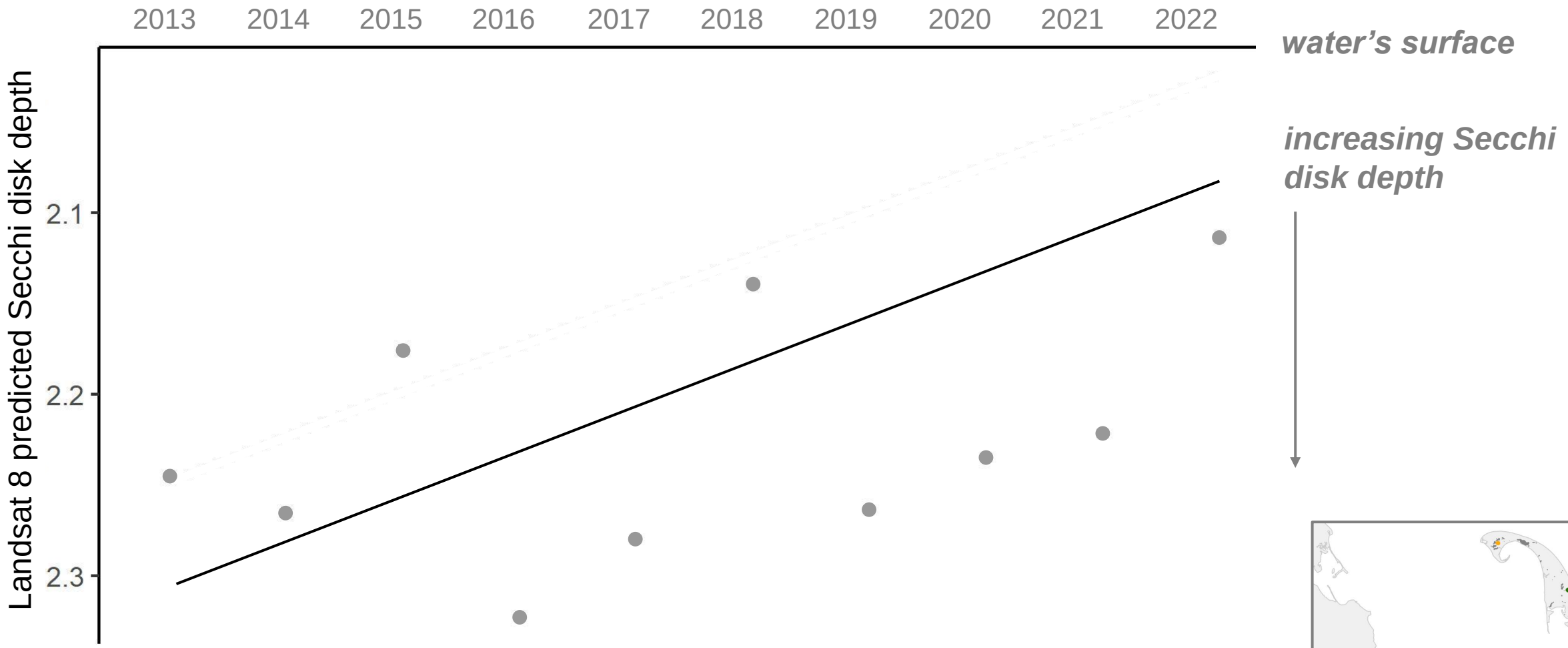


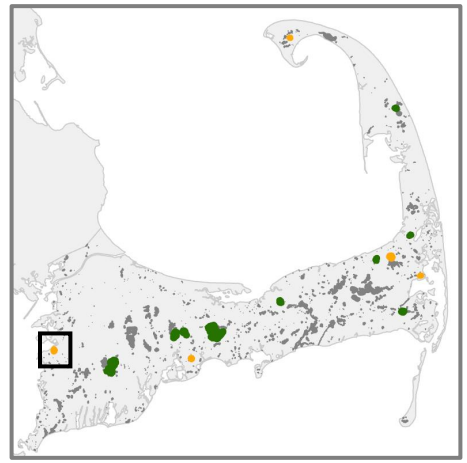
***180 ponds** were assessed for trends in Secchi disk depth*

***15 ponds (8%)** had a statistically significant change from **2013-2022**; **5 ponds decreased** in Secchi disk depth & **10 ponds increased** in Secchi disk depth*

No monotonic change
Decreased Secchi disk depth
Increased Secchi disk depth

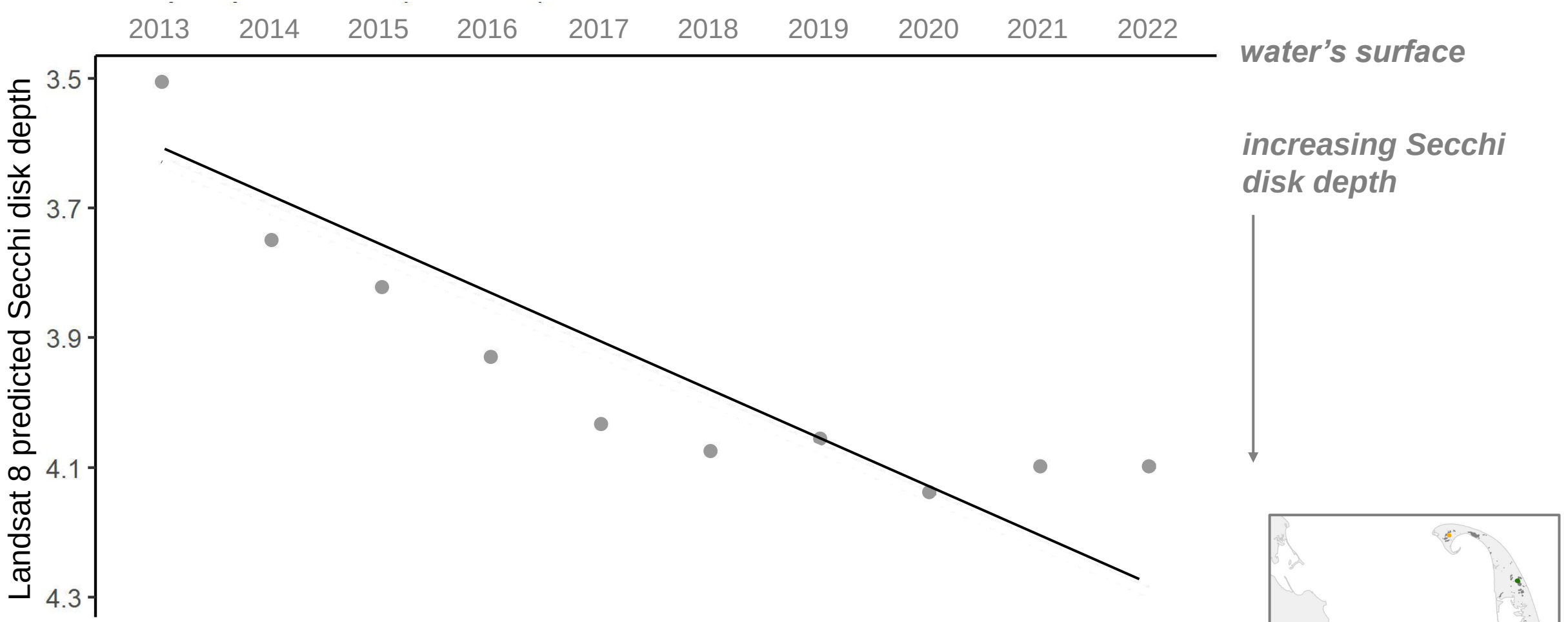
Cedar Lake (Town of Falmouth)

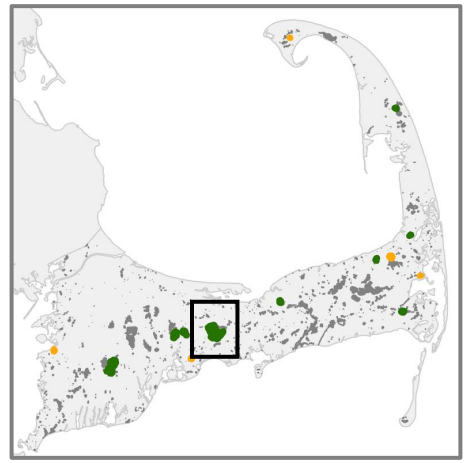




***10% decrease** in Secchi disk depth from 2013-2022 (**deteriorating water clarity conditions**)*

Wequaquet Lake (Town of Barnstable)





***18% increase** in Secchi disk depth from 2013-2022 (**improving water clarity conditions**)*

Water clarity changes

Generally, water clarity conditions across the Cape have been stable over the past decade

Of the 180 ponds assessed for changes in water clarity, 15 (8%) indicated a statistically significant change

Five of these ponds decreased in their Secchi disk depth, indicating deteriorating water clarity conditions

Ten of these ponds increased in their Secchi disk depth, indicating improving water clarity conditions

No apparent spatial patterns (not yet statistically tested)

Next steps

Refine random forest approach as additional field data become available

Statistically assess spatial patterns in both agreement and trends

Explore the inclusion of additional Landsat satellites in trend assessments, which can potentially provide a 40-year time series of Secchi disk depth

Assess drivers of Secchi disk depth to better understand past patterns and to characterize future changes